THE HOME SATELLITE TV INSTALLATION & TROUBLESHOOTING MANUAL

1986 Edition

FRANK BAYLIN

BRENT GALE

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Cover Illustration
Courtesy of Precision Satellite, Inc.

Published by Baylin/Gale Productions

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First Edition

First Printing: August 1985

ISBN: 0-917893-02-6
LCCCN: 85-71662

DEDICATION

We dedicate our book to
Arthur C. Clarke, pioneer
and
All the hard working, honest satellite TV dealers

ACKNOWLEDGEMENTS

We are grateful to those who made this enormous task a little easier and who helped to improve the final product. Both H. Taylor Howard and Michael L. Gustafson read the manuscript and gave technical guidance. Thanks to Toby Olberding for his help in telecommunicating the files from our PC to the typesetting equipment. Greg Johnson of Echosphere kindly provided the satellite tracking program. Christopher Schultheiss, publisher of STV Magazine, allowed us to use his carefully measured footprint maps. Richard Zlotky, president of Earthbound, Inc., added some excellent information about wind loading. Mark Widner of Chaparral provided materials to create the installer's pre- and post-installation tables. Precision Parabolics of Canada kindly provided the cover artwork.

We appreciate the efforts of Laurie Gallus, who drew the free-hand illustrations and Amy Lockard, who created all the line drawings.

We both wish to thank all of our satellite TV customers. In particular, Frank Baylin remembers the lesson learned one night at 2:30 AM when he received a call from a terrified customer about an actuator running wild. Brent Gale recalls the installation that had to be completed on Christmas Eve in temperatures of 15 °F below zero.

Last but not least, thank you to all the hard working staff at Johnson Publishing Company in Boulder, Colorado with special thanks to Gail Witt, Terri Carr and Ron Blommel for their assistance.

THE COMPLETE HOME SATELLITE TV INSTALLATION MANUAL

FOREWORD

Television from a satellite transmitted directly to the home is what I call an "ultimate" technology. This is so because it is the final way the job will be done - other delivery methods such as terrestrial broadcasting and cable have had, and will continue to have, a place if they learn to exercise their unique capabilities, but they have never been more than interim technologies because they left so many homes unserved or underserved.

How many homes are there? In the United States roughly 100 million! Of these 10 to 20 million get little to no television and are, of course, a prime market. But the market is not limited to those homes, for once a viewer sees what comes from the satellite - more than a hundred channels of perfect pictures with a total freedom of choice - they will never again be happy with any other type of service.

One of the problems with satellite TV is that, upon first encounter, it all seems so "space age" and complicated. It doesn't have to be and an engineering degree isn't needed any more than you need a ship captain's license to ride a surfboard, for the engineering has been done, the equipment for the home has matured, and the "high tech" can be invisible to the viewer.

From the installers standpoint it is a technical business, however, and there is much to learn if the goal of invisibility is to be achieved. If you are in the satellite television business or thinking of entering it, you have probably amassed a collection of magazine articles, old handbooks, and a private notebook but have been unable to find one source book that covers everything. This book, "The Home Satellite TV Installation and Troubleshooting Manual" puts it all in one place and will make it possible to throw out that old collection.

Once you have mastered the material in this book and have done a few installations you will be in a position to ride the crest of the satellite TV wave into the future.

H. Taylor Howard
Director of Research
Chaparral Communications, Inc.

August 1985

I. OVERVIEW OF SATELLITE COMMUNICATION THEORY

A. INTRODUCTION

Modern satellite communication is made possible by combining the skills and knowledge from space technology with those from microelectronics. Every year more sophisticated and heavier satellites are being launched into orbit for ever lower costs. In fact, the evolution of satellites is a perfect example of how the boundary between computers and communications is quickly disappearing. Satellite communications is one of the most rapidly growing and evolving business in the 1980's.

The concepts behind satellite broadcasting, first stated in Arthur C. Clarke's ground-breaking article in the October 1945 edition of Wireless World, are rather simple. Signals are beamed into space by an "uplink" antenna, received by an orbiting satellite, electronically processed, broadcast back to earth by a "downlink" antenna and received by an earth station located anywhere in the satellite's "footprint".

Most communication satellites are sited in the "Clarke Belt" or the "geosynchronous" arc at 22,247 miles directly above the equator. This circle around the earth is unique because in this orbit the velocity of satellites matches that of the surface of the earth below. Therefore each satellite appears in one fixed orbital slot in the sky above so that a fixed antenna can always be aimed towards any chosen geosynchronous satellite.

The pioneer communication satellites like Telstar were placed into lower, more complex elliptical orbits because sufficiently powerful launching vehicles were not available to lift them into the distant geosynchronous arc. For example, one of the first communication satellites, Telstar, had to be tracked by very costly and bulky equipment mounted on rails to allow movement. (For more details on the history of both the technology and the organizations underlying satellite broadcasting see Satellites Today - The Complete Guide to Satellite Television by Frank Baylin.). Today some communication satellites are still launched into hard-to-track elliptical orbits most often for security reasons exampled by U.S. military vehicles. The Soviet Molniya television broadcast satellites are also still postioned in these more complex elliptical paths.

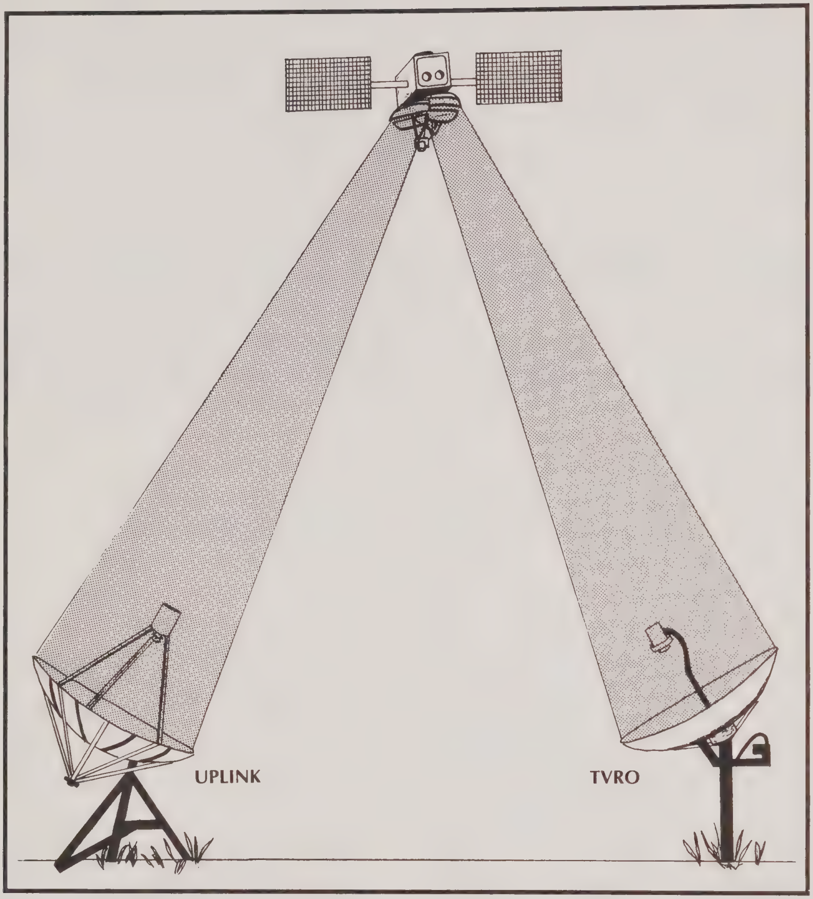


Figure 1-1. The Satellite Communication Circuit. *Broadcast signals are relayed by an uplink via satellite to any number of receiving stations.*

B. SYSTEM OPERATION

The satellite communication circuit consists of an uplink, a communication satellite and an unlimited number of earth-based receiving stations. The overwhelming strength of satellite broadcasting is based on its ability to reach this unlimited number of customers irrespective of their geographic location.

The uplink is a complex system using many hundreds of watts of power to send a beam of microwaves to a pin-point target in space. Uplink antennas operate like car headlights which have a small light at the center and a parabolic reflector. High power microwaves aimed towards the antenna surface are reflected into a

beam directed into space. Because of the power levels (typically about 500 watts) involved, the potential for interference with other communicators, and the fact that just one antenna relayed to any chosen satellite can be detected by millions of receiving stations, uplinks are carefully regulated by the FCC. A "pirate" uplink could certainly create havoc.

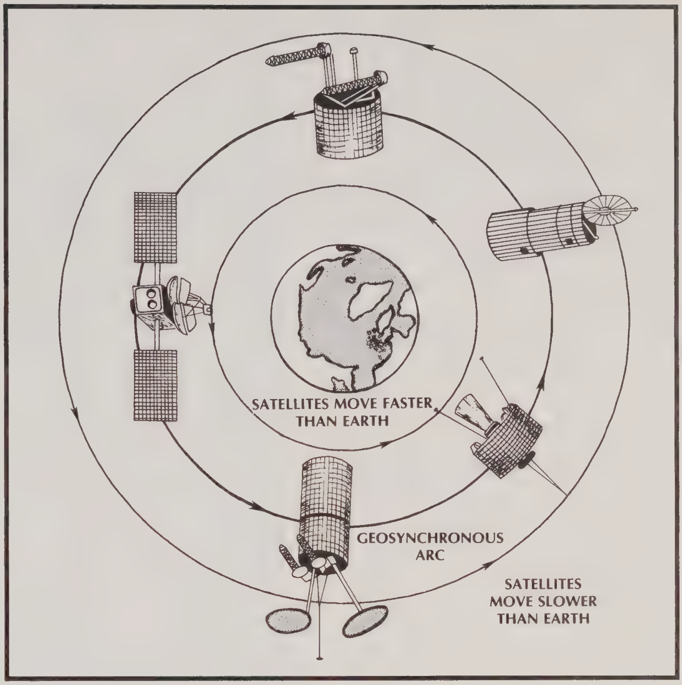


Figure 1-2. The Geosynchronous Arc. *Satellites above or below this orbit at 22,247 miles over the equator rotate more slowly or rapidly, respectively, than the speed of the earth below. Only satellites in the geosynchronous orbit stay in a fixed position relative to an observer on the earth below.*

Uplinks are used by many segments of the business community including TV and radio stations, telephone companies, and data networks. In many cases, an on-site uplink is fed by direct cable links from broadcast studios, telephone lines or computers. Many television stations relay signals by conventional, off-air methods to distant uplinks and thus to communication satellites for rebroadcast. Groups needing uplink facilities on an occasional basis for teleconferencing, one-time sporting events or other special happenings have the option of "taking Mohammed to the mountain," i.e. of bringing the equipment directly to the action. This is often a viable economical alternative to broadcasting over-the-air to a fixed uplink site. This leasing of portable uplinks complete with all equipment and operating crews is a sensible alternative in view of the average $300,000 price tag for a fully operable on-site uplink.

Geosynchronous broadcast satellites receive the uplinked signal, change the frequency of the message and then broadcast it to any chosen geographic area below. Downlink antennas can target up to 40% of the earth's surface with so-called global beams, can broadcast to selected countries or continents, or can pinpoint smaller areas with spot beams. To illustrate, many U.S. broadcast satellites have one antenna which blankets the continential United States and a second smaller one which directs a more localized beam to the Hawaiian islands. A good example of such a satellite is Satcom F-5, known also as Aurora.

The earth station consists of a large antenna to collect and concentrate as much of the very weak downlinked signal as possible to its focus. The feedhorn, located precisely at the focus, channels radiation reflected and concentrated by the antenna into the first active component, the low noise amplifier (LNA). Then a short length of cable relays these signals into a device called a downconverter which lowers the range of frequencies. Following downconversion, this message is cabled in-doors to the video receiver and processed into a form understandable by either a television or a stereo. An earth receiving station is in essence an uplink operating in reverse.

C. MICROWAVES

The medium behind the entertainment and information relayed by satellite broadcasting is invisible, extremely low power microwaves. Microwaves and radio waves, the agent by which radio, conventional television and other man-made devices work, are called electromagnetic waves. If we could see such a wave, it could look like the waves that travel outward in concentric circles when a pebble is tossed into a pond. Radio waves and microwaves are similar in concept to the waves of vibrating air molecules that we know as sound. While sound travels at a plodding 760 miles per hour, radio waves and all electromagnetic waves travel at the speed of light, 186,000 miles per second. At this speed, a signal travels from an uplink antenna to a satellite and back again in about 4 tenths of a second.

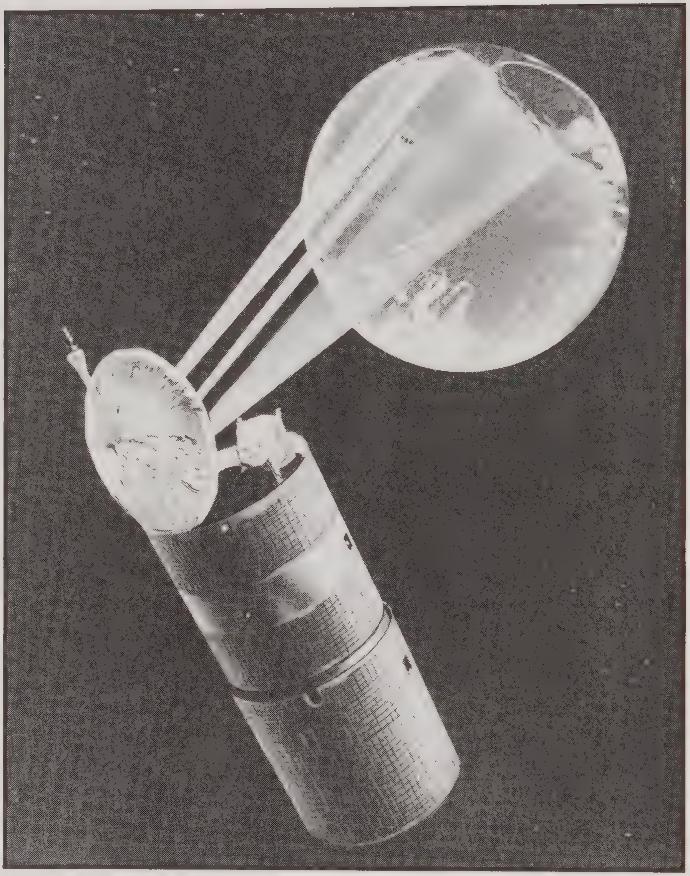


Figure 1-3. Galaxy Satellite. *The Galaxy family of satellites have downlink antennas which target the continental United States, the Hawaiian Islands and Alaska. (Courtesy of Hughes Aircraft Company).*

Frequency

One important property of radio waves is their frequency, the number of vibrations that occur every second. Just as the frequency of sound vibrations determines whether a musical note is either a soprano or a bass, so the frequency of radio waves determines whether they are used for regular AM radio broadcasts or for satellite television relays. Microwaves have frequencies in excess of one billion cycles per second (known as one gigaHertz and abbreviated 1 GHz). By comparison, the electricity from an wall outlet has a frequency of 60 Hertz, or 60 cycles per second. So that each second the voltage changes from positive to negative 60 times.

Many seemingly different phenomena encountered in nature including light, X rays, infrared heat rays, microwaves used for both cooking and communicating and gamma rays

from the cosmos are electromagnetic waves (see Figure 1-9). Surprisingly, the only difference among them is their frequency. Since all electromagnetic waves travel at the same speed, the speed of light, as the frequency increases the wavelength must decrease. For example, the wavelength of visible light is comparable to the dimensions of atoms and molecules, and their frequencies are many billions of billions of cycles per second. In contrast, microwaves have lower frequencies of one to fifty gigaHertz and wavelengths ranging from one foot to fractions of an inch. Radio waves have wavelengths which can be miles long and frequencies in the millions of cycle per second (megaHertz or MHz) range.

Power

A second property of electromagnetic waves is their power or strength measured in units like watts per square meter. So, for example, 10 watts per square meter means that the power passing through each square meter is ten watts. Satellite TV broadcasts are usually received by an antenna at powers less than one billionth of one billionth of a watt per square meter!

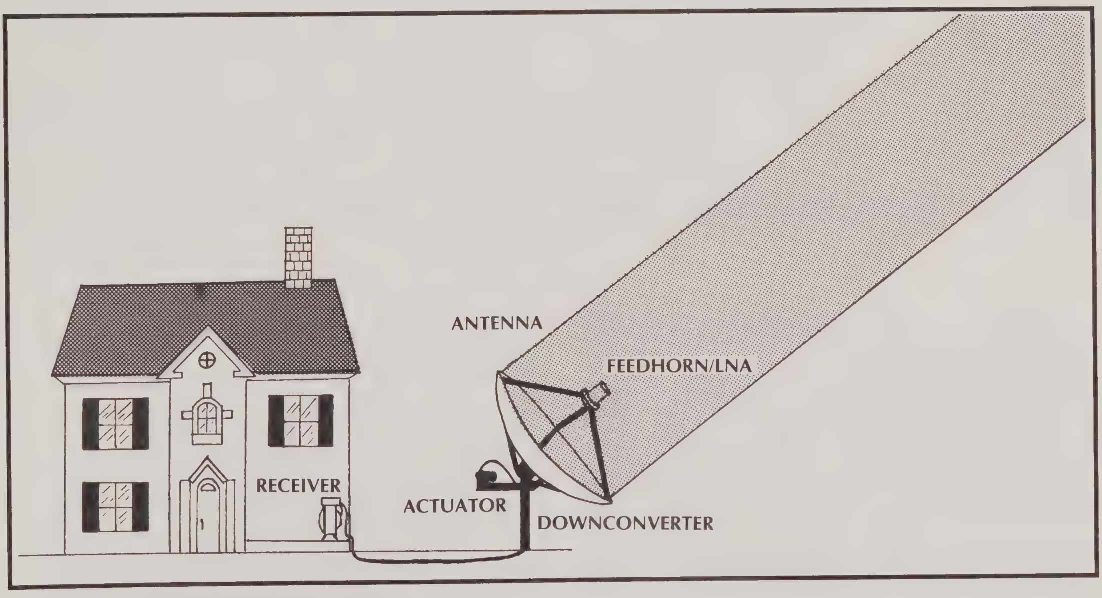


Figure 1-4. Typical Earth Station. *Signals are captured and focused by the antenna into a feedhorn and low noise amplifier. These are relayed by cable to a downconverter and then into a satellite receiver/modulator. Any number of televisions can be fed by the system.*

Polarization

A third important property of all electromagnetic waves is polarization. To understand this idea we can imagine a car driving along a highway. It can travel to the same destination by following a curving road along flat ground or by following a straight road over rolling hills. Horizontally polarized waves vibrate in a horizontal plane like the car travelling along a curving road. Vertically polarized waves vibrate in a vertical plane.

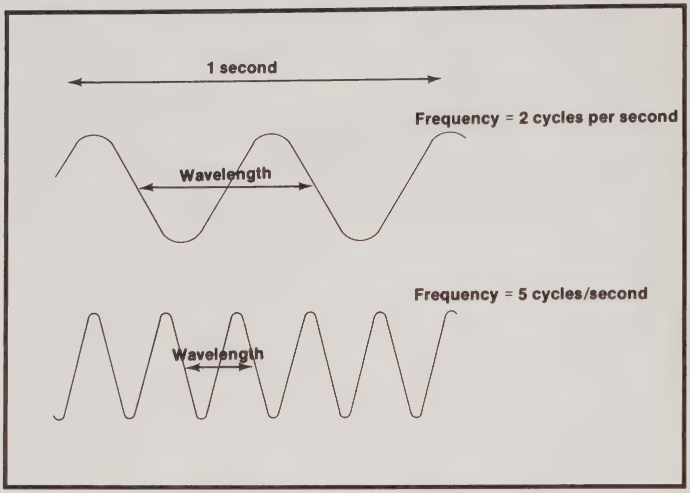


Figure 1-5. Frequency. *All electromagnetic waves are defined by how many vibrations occur each second, the frequency. Higher frequency waves have shorter wavelengths and vice versa. For example, a 4 gigaHertz microwave signal has a 2.95 inch (7.5 centimeter) wavelength.*

Microwaves can also be circularly polarized. Such formats though rarely used in domestic U.S. broadcasts are often used in satellite communication in other countries. A left-hand circularly polarized wave has its plane of vibration following a left hand circular motion as it travels. Right-handed circularly polarized waves would follow a right circular moving plane of motion.

D. COMMUNICATION FUNDAMENTALS

The same principles underlie all forms of man-made communication. The first step is creating and coding the message. Next this information must be modulated or added onto the medium designed to carry the signal. At the receiving end, the signal is demodulated and the original information is extracted. The amount of information carried is determined by its "bandwidth." The power of the signal can be amplified (increased) or attenuated (decreased). And unwanted signals or noise are always present to hinder perfect communication.

Coding the Message - Analog and Digital Signals

Any message, whether it be the image and voice of an entertainer or details of stock-market transactions, must first be changed into a form that can be relayed by radio waves. Analog coding methods mimic the pattern of a message by changes in electrical voltages. For example, a voice can be changed into an analog signal by a microphone that creates a voltage pattern

determined by the loudness and frequency of the sound. The louder the sound, the higher the voltage. The higher the sound frequency, the more rapid changes occur in this voltage.

By contrast, a digital coding method uses only the numbers 0 and 1 to convey all information about these voltage levels and frequencies. For example, a photograph can be described by a long series of 1s and 0s that are coded so that some impart information about the location of the dots composing the picture and other determine the brightness and color of the dots. Computers exclusively use digitally coded messages.

Uplinks can relay either digital or analog forms of the same message. Converters that can translate between these two languages are available. For example, while most TV broadcasts are expressed in analog form, the trend is to use digital transmissions as newer and higher quality televisions are developed and as satellites are packed with more sophisticated electronics allowing higher amounts of information to be transmitted.

Figure 1-6. Vertically and Horizontally Polarized Waves. *Earth station feedhorns, the funnel which collects microwaves at the dish focus, are capable of distinguishing between vertically and horizontally polarized waves. These formats are used by many broadcast TV satellites.*

Modulation - Adding the Message to Carrier Waves

Analog or digital signals are impressed upon radio or microwaves by a process called "modulation." Once the message is modulated onto the carrier wave (which carries the information) of an acceptable frequency it can be relayed from a sending to a receiving location whether it is via a satellite link, off-air or along a cable route. Radios, televisions and other communication equipment demodulate or extract the original message from the carrier wave.

The simplest method to modulate a carrier wave is to switch it on and off. For example, Morse code can be relayed as a series of dots and dashes by turning the carrier wave on and off. The most familiar methods of modulation are amplitude modulation (AM) and frequency modulation (FM) as encountered, for example, in AM and FM radio broadcasts. Amplitude modulation varies the power of a carrier wave in accordance with the voltage level of the message being carried while frequency modulation varies the frequency of the carrier in response to the message.

Each of these types of modulation has advantages and disadvantages. On one hand, AM messages must have relatively high powers to be capable of travelling long distances without being weakened too severely for clear reception

by atmospheric disturbances and other forms of noise. Such relays are also more prone to picking up static than are FM messages. On the other hand, FM signals need relatively lower power for successful, long distance transmission, but must use a substantially wider range of frequencies than AM messages would to carry the same amount of information. Satellite messages are frequency modulated for these reasons. As signals cover the long distances between uplinks, satellites and earth receiving stations, their power becomes so low that AM transmissions would be unusable. Also, since extremely high frequencies are used in satellite communication the very wide bandwidth as required by FM broadcasts is available.

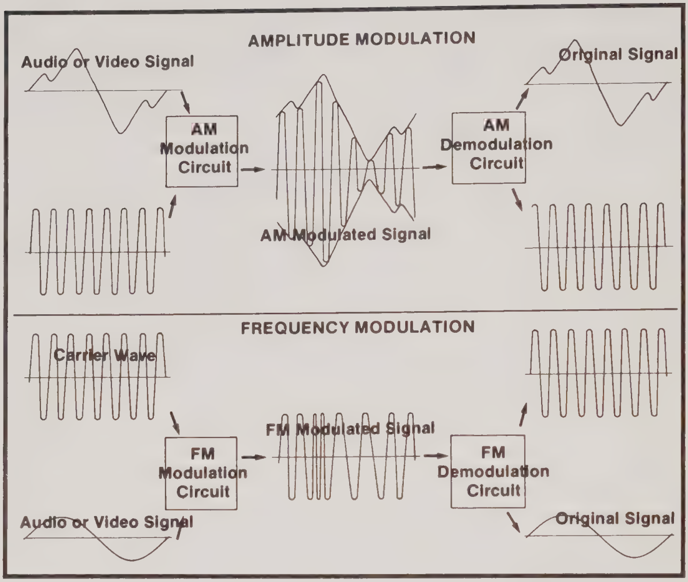


Figure 1-7. Modulation. *Two formats used to impress a signal onto a carrier wave are amplitude and frequency modulation. This modulated audio, video or data signal can then be relayed by cables, over-the-air or by satellite to its destination.*

Today, other methods of signal modulation have been designed to allow any given carrier wave to transmit a maximum amount of information over as narrow a range of frequencies and with as low a power as possible. Such efforts to conserve the available resources are quite sophisticated but are often used in conjunction with the two basic types of modulation.

Bandwidth - How Much Information Can be Carried?

Just as a large-diameter pipe can carry more water than a small one, so a signal spanning a wide band of frequencies can carry more information than can one using a narrow band. This range of frequencies is termed the "bandwidth." For example, a TV message relayed in the frequency range from 54 to 58.2 MHz has a bandwidth of 4.2 MHz (megahertz or million cycles per second) which is spread out to as much as 36 MHz in a satellite FM broadcast.

Each communication medium requires a characteristic bandwidth. Devices such as television need a substantially wider bandwidth than do radio or telephone because much more information is necessary to recreate a picture than music or a voice. For example, channel one on U.S. broadcast satellites is located between 3.70 and 3.74 GHz and has a 36 MHz bandwidth. Voice channels, however, normally require a bandwidth of only 3,000 to 4,000 cycles per second for quality sound reproduction.

Amplification and Attenuation

Signals used for communication must often be amplified during their voyage from sender

to receiver to preserve the information intact because their power is usually weakened or attenuated. In the same fashion that a photograph is enlarged but not changed, correct amplification retains the original message. All televisions, radios, stereos and other communication equipment amplify a signal before demodulation occurs. For example, messages beamed into space from an uplink antenna are weakened on their voyage to a satellite as the signal becomes spread out and is absorbed by water vapor, clouds and other materials. The purpose of a satellite receiving antenna is to collect and concentrate these weak signals like a magnifying glass.

Occasionally, a signal will be intentionally attenuated. For example, a cable TV headend may deliver an excessively powerful signal to a feeder line which could over-drive connected TVs and cause distortion. Pads or line attenuators are then inserted to reduce the signal power.

Noise - Hindering Clear Communication

In a perfect communication system signals would be relayed with no interference or noise. However, noise is present in all matter at temperatures above absolute zero, K, the temperature at which all molecular motion ceases. (There is no temperature colder than absolute zero! Note K is an abbreviation for degrees Centigrade above absolute zero.) Noise is caused by the endless motion of the molecules that compose all matter. These small, vibrating charged particles generate electromagnetic waves that can mask the organized signal sent by man-made devices. Noise from the environment becomes stronger as the temperature increases.

Satellite dishes detect noise from the warm ground. The temperature on an average day, 62°F, is 290 K. Outer space also generates noise at about 4 K, as a result of the "big bang." So an antenna pointed straight towards earth like one on a satellite, will pick up an additional 290 K; one on earth pointed straight into space will see approximately 10 K of noise, about 4 K from space and the rest from the ground. Receiving antennas also pick up more of this environmental noise as the signal bandwidth increases. Furthermore, noise is generated by internal heat in amplifiers, receivers and other electronic equipment.

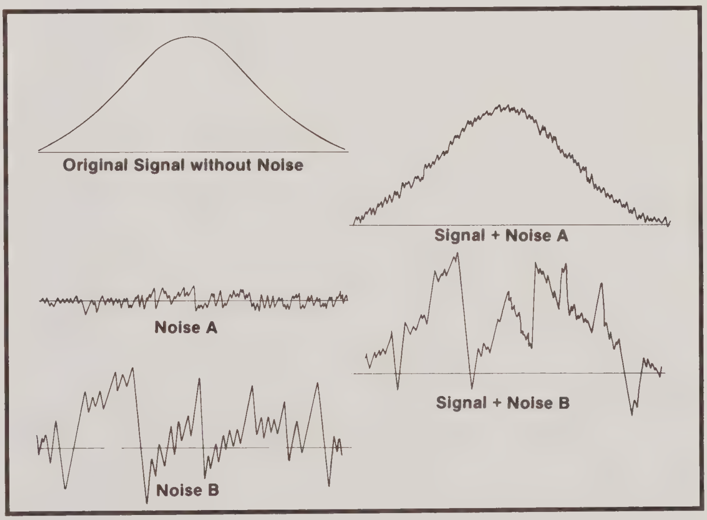


Figure 1-8. Noise. *Excessive amounts of noise can completely garble a radio or television signal. Moderate amounts of noise are manageable.*

Man-made signals not intended for the receiving station are also considered a type of noise called interference. Terrestrial interference, known as TI, results when earth-based communications other than those

from satellite broadcasters are inadvertently received by an earth station.

Noise is always present in satellite communication systems. The quality of a communication link is determined by the ratio of signal-to-noise power. For example, if a signal of 10 watts is received along with 5 watts of noise, a S/N of 2, the picture quality could be poorer than if a signal of 4 watts was received with only 1 watt of noise, a S/N of 4. Typically, televisions must receive a signal having power greater than 63,000 times the accompanying noise in order for a "high-quality" picture to be received.

E. FCC FREQUENCY ALLOCATIONS

In the United States, the Federal Radio Commission, and later the Federal Communications Commission (the FCC) in concert with the International Telecommunication Union have kept order in the airways by successfully assigning portions of the radio wave spectrum to different communication media and users.

In fact, the history of communication is unfolded by an exploration of these frequency assignments. As technology progressed, man has become capable of using higher and higher frequencies. Wire transmissions were first relayed with relatively low frequencies, since the radio waves used by the pioneers were limited in frequency by the rather primitive available electronics. When radio waves above 1.5 megaHertz frequency were first produced by man, the FRC delegated them to the "hams" because, at that time, they could not see a use for this region of the spectrum. As technology progressed, coaxial cable transmission, microwave relays and then satellite communication were allocated successively higher frequencies.

Even with all the new man-made forms of communication, a relatively small portion of the electromagnetic spectrum is presently being used. However, in those ranges where frequency space is being used, these resources are in heavy use and competition for allocated space can at times be fierce. As a result, innovative methods have been developed to "reuse" or to have more than one user simultaneously share the same portion of rare spectrum.

TABLE 1-1. FCC ASSIGNMENT OF SOME RADIO FREQUENCIES

Frequency (MHz)	FCC Assignment
3-54	Mobile Radio
54-72	TV Channels 2-4 (VHF)
72-76	Radio Services
76-88	TV Channels 5 & 6 (VHF)
88-108	FM Radio
108-120	Aeronautical
120-136	Aeronautical
136-144	Government
144-148	Amateur Radio
148-151	Radio Navigation
151-174	Land, Mobile, Maritime
174-216	TV Channels 7-13 (VHF)
216-329	Government
329-890	TV Channels 14-83 (UHF)

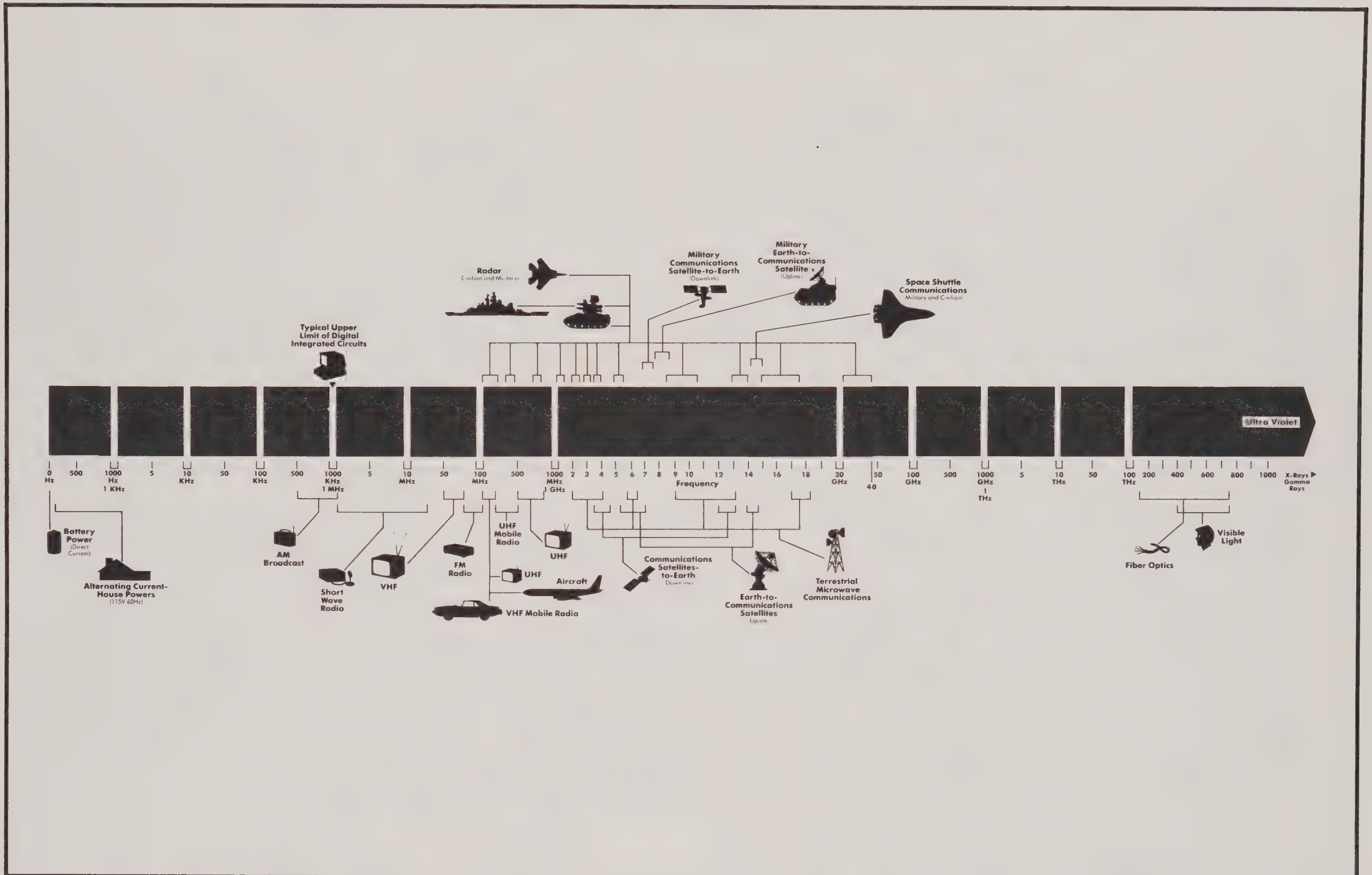


Figure 1-9. FCC Frequency Allocations. *This chart depicts how the FCC has assigned the frequencies in the electromagnetic spectrum to the many types of manmade communication. (Courtesy of Avantek Corporation).*

F. WHY MICROWAVES?

Microwaves have been used in satellite communication for five specific reasons. First, higher frequency electromagnetic waves have the potential for relaying larger quantities of information because, as the frequency increases, any given bandwidth becomes a smaller fraction of the operating frequency. For example, a 1 MHz wide bandwidth located in the 10 MHz region of the spectrum occupies relatively more space there than does the same bandwidth in the 10 GHz region. Since more bandwidth is available, wider bands with higher information capacities can be used at microwave frequencies. Therefore, microwaves can relay as much information as possible per satellite and thus can pay off the expensive investment in satellite launching, operation and maintenance more quickly.

Figure 1-10. Line-of-Sight Relay Station. *Before the advent of satellite broadcasting microwaves had to be relayed via cables or between line-of-sight stations like the one shown here. (Courtesy of the Microwave Filter Company).*

A second reason for using microwaves stems from the requirement for uplink antennas to a aim highly directional beam towards an extremely small target in space. Physics dictates that electromagnetic waves can be better focused by an antenna that is substantially larger than the wavelength of radiation it is managing. For example, sending a directional beam of AM radio signals having 100-meter long wavelengths would require an extremely large, cumbersome and expensive antenna. Since 6 GHz microwaves have wavelengths of approximately 5 centimeters (2 inches), a 15-foot uplink dish can aim most of its radiation into a very narrow beam, and relatively low power can be used.

Third, microwave transmissions to satellites or between earth- based, line-of-sight relay stations are not as susceptible to noise from atmospheric disturbances as are lower frequency transmissions. To illustrate, several times each year, for periods as long as two or three days, shortwave radio is useless for long-distance communication because sun-spot activity disturbs the required reflection of these relatively low frequency radio waves by the upper atmosphere.

Fourth, the most important property of microwaves that determines their use in satellite communication is their ability to pass through the upper atmosphere into outer space. Below frequencies of approximately 30 MHz, a radio wave will be reflected back from the ionosphere layer in the atmosphere towards earth. Since microwave frequencies are far above the 30 MHz range, they easily pass through the ionosphere layer shield.

Fifth, the microwave region of the electromagnetic spectrum was a relatively virgin

territory during the late 1950s and '60s when frequency spectrum was being allocated by the FCC and the International Telecommunications Union. Lower frequency space was already occupied by many different communication media and users.

As geosynchronous orbital space has become increasingly populated, progressively higher microwave frequencies have been allocated to satellite communications. Until the early 1980s most satellite broadcasters used C-band frequencies. Today, portions of the Ku-band are employed and higher frequency bands are being eyed by numerous potential users. However, a technical difficulty lies in this path. Microwaves are depolarized and more strongly absorbed by water vapor in the atmosphere at higher frequencies. So higher power relays must be used to counteract this effect.

If satellite broadcasters in the United States had been allocated space in the S-band from the pioneer days of satellite TV, lower cost, more readily available techniques could have been used. The equivalent of the FCC in India recognized this loss caused by absorption in the atmosphere. They now use 2 GHz, S-band satellite relays.

TABLE 1-2.
MICROWAVE FREQUENCY BANDS

Band Name	Bandwidth (GHz)
L-band	0.39 to 1.55
S-band	1.55 to 5.2
C-band	3.70 to 6.20
X-band	5.20 to 10.9
K-band	10.9 to 36.0

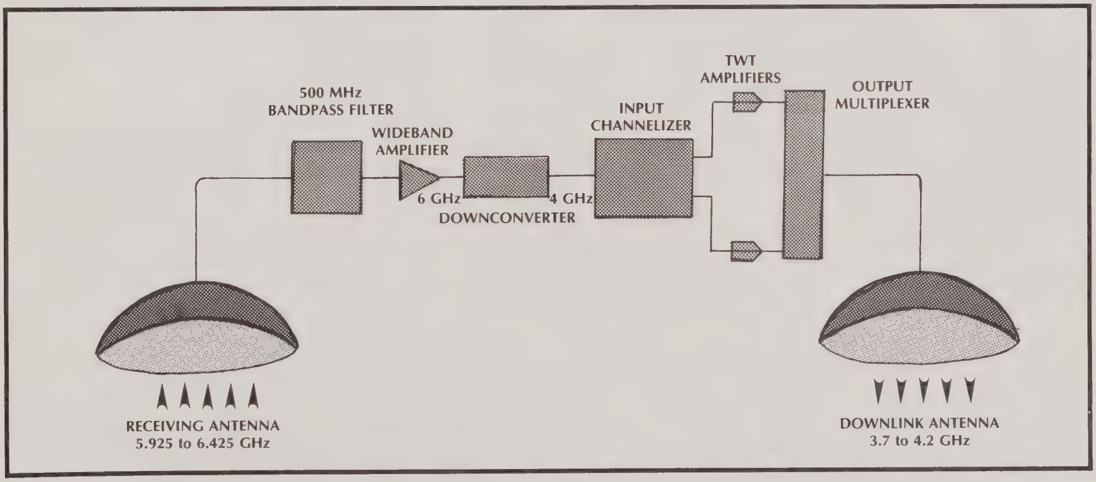


Figure 1-11. Schematic of Satellite Operation. *Communications satellites receive microwaves sent into space from an uplink. This signal is then amplified, lowered in frequency and broadcast back to earth.*

G. SATELLITES

Satellites are the key component in the telecommunication revolution. Our communication system is now greatly improved because any locations within a satellite's "view" can be linked without the use of expensive cables or line-of-sight relay towers. Furthermore, a communication satellite operating as a relay in space can serve vast areas of our globe at once.

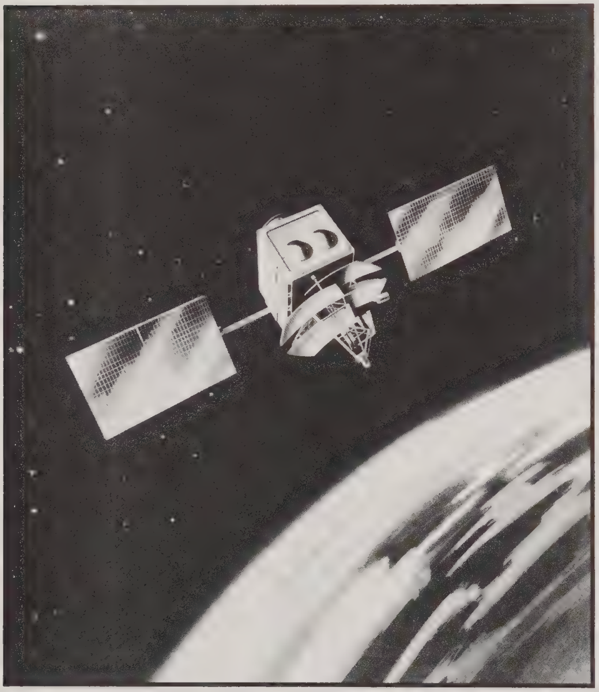


Figure 1-12. Satcom Satellites. *The large wing-like structures are solar cells which provide on-board power. The antennas receive and transmit the microwaves. (Courtesy of RCA American Communications).*

Satellite Operation - Audio and Video Channels

Uplinked signals have powers of fractions of a millionth of a watt when received by geosynchronous satellites. In the heart of this communication vehicle, typically about the size of a small truck, these signals are amplified many thousands of times, are shifted to a lower frequency range and then are broadcast back to earth.

This frequency conversion reduces terrestrial interference at the receiving station below. If this was not the case, some of the uplinked signal could be inadvertently detected by receiving stations near uplink sites along with the desired signal. American C-band circuits use an uplink having a 500 megaHertz bandwidth spanning the range from 5.925 to 6.425 gigaHertz and the same bandwidth shifted to the lower range of 3.7 to 4.2 gigaHertz for the downlink. Ku-band relays typically uplink signals from 13.7 to 14.2 gigaHertz and downlink from 11.7 to 12.2 gigaHertz, both ranges also spanning a 500 megaHertz bandwidth.

All the power to carry out these electronic functions is provided by the sun's energy and captured by arrays of solar or photovoltaic cells. The illustration of Satcom I shows these arrays as larger wing-like structures. The smaller central features are the receiving and downlink antennas.

Television Channel Formats

The number of television channels, telephone conversations or the amount of data transmitted is related to satellite electronic design. The early Western Union vehicles such as Westar I and II relayed 12 television programs simultaneously; the RCA series of Satcom and most modern C-band broadcast satellites handle 24 at least channels.

How is the number of channels determined? The 500 megaHertz microwave band can be subdivided into twelve 40 megaHertz segments plus a remainder of 20 megaHertz. Since a 36 megaHertz bandwith is sufficient to broadcast a high quality television picture, Western Union designed their early satellites to carry 12 channels having 36 megaHertz bandwidths with 4 megaHertz protection regions, guard bands, between each channel to eliminate the possibility of crosstalk. Each channel was handled separately on-board the satellite by a device called a transponder.

Engineers designing the Satcom I vehicle were somewhat more creative. They doubled the number of channels which could be relayed by this 500 megaHertz total bandwidth by a technique called frequency reuse. All even channels were transmitted earthward with horizontal polarization; all odd channels were sent with vertical polarization; and the frequency centers of these cross polarized channels were offset from each other for further security against crosstalk. Since each earth station was equipped to detect only vertical or horizontal polarization at one time there could be some overlap between the frequencies used for the odd or even channels without interference between channels. Of course, when an earth station is required to receive all 24 channels simultaneously it must be capable of detecting both horizontal and vertical channels at the same time.

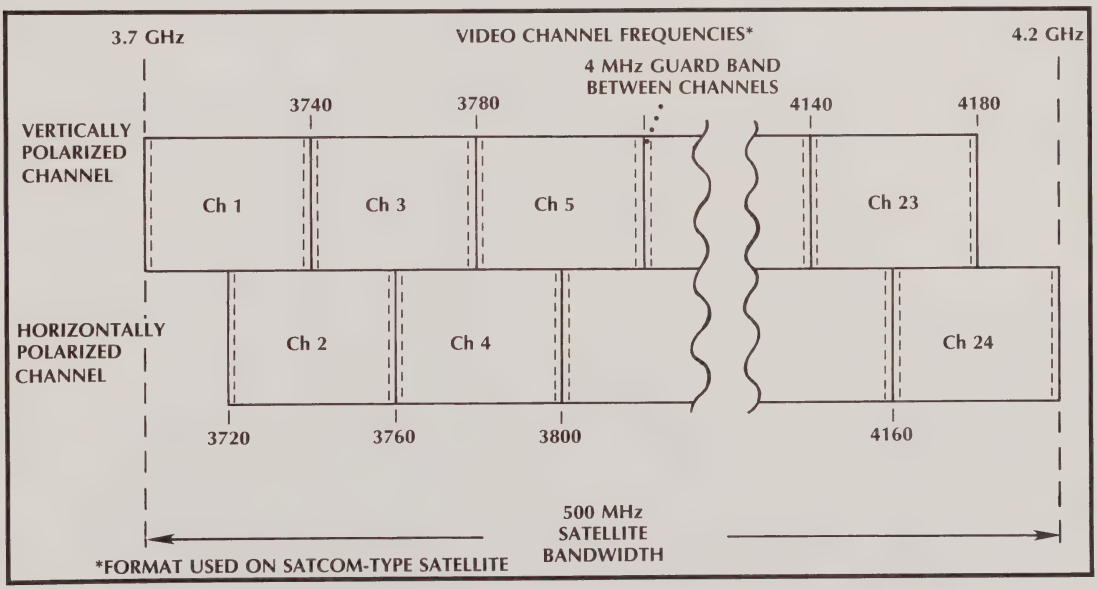


Figure 1-13. Video Channel Formats. *Most American broadcast satellites are designed to relay 24 channels each having a maximum bandwidth of 36 megahertz. 12 channels each are relayed by vertically and horizontally polarized waves. The Satcom, Comstar and Telstar series of satellites have odd channels vertically and even channels horizontally polarized as shown in this figure. The Galaxy, Westar, Spacenet and Anik vehicles have reversed polarity schemes.*

TABLE 1-3. SATELLITE CHANNEL CENTER FREQUENCIES

Downlink Transponder Number	Frequency (MHz)
1	3720
2	3740
3	3760
4	3780
5	3800
6	3820
7	3840
8	3860
9	3880
10	3900
11	3920
12	3940
13	3960
14	3980
15	4000
16	4020
17	4040
18	4060
19	4080
20	4100
21	4120
22	4140
23	4160
24	4180

Note that the format used for U.S. broadcast satellites is by no means the only one accepted by other nations. For example, European satellites relay their television broadcasts over satellites having 700 megahertz bandwidths.

Audio Channel Formats

Each transponder manages a 36 MHz wide band of frequencies. When an earth station receives and processes this information, the resulting signal is contained in a band of frequencies from near zero to about 10 MHz. The video signal is contained between zero and 4.6 MHz. All the remaining space can be used for audio channels, some of which is stereo or mono sound that matches the television picture and others which are totally separate messages.

These audio signals are carried on "audio subcarriers." Most U.S. television broadcasts relay the audio information on a 6.8 MHz subcarrier or occasionally, on both 6.2 and 6.8 MHz subcarriers for transmitting stereo sound.

Some satellite transponders operate in the single channel per carrier mode, known as SCPC, where only audio information is relayed. For example, National Public Radio dedicates an entire transponder (Westar IV, transponder III) exclusively to their audio broadcasts. (For further information see Hidden Signals on Satellite TV by Thomas Harrington and Bob Cooper.).

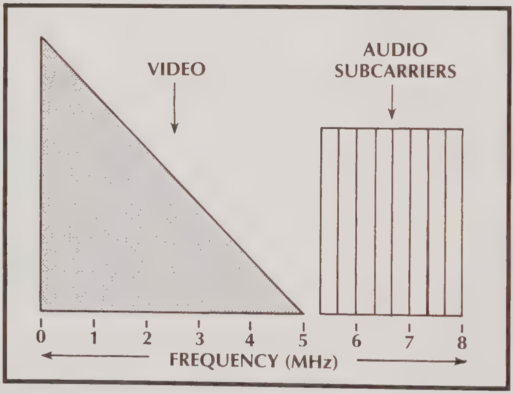


Figure 1-14. Audio Channel Formats. *Audio information is relayed on subcarriers having center frequencies ranging from 5 to 8.5 megaHertz. Usually the sound accompanying TV broadcasts is relayed on a 6.8 MHz subcarrier.*

The Downlink Path and Satellite Footprints

Satellite downlink antennas broadcast all these processed microwave signals to any chosen geograpic region below. The design of such antennas is in itself a science and an art. The satellite footprint is a reflection of the downlink antenna geographic coverage and the microwave power generated by each on-board transponder. As would be expected power levels are higher in regions targeted by the main axis of the downlink antennas and weaker in off-target areas. This partially explains why larger dishes are required for equivalent reception in Florida than those needed in Nebraska when viewing programs from a satellite designed to target the whole continental United States. Nebraska is at the center of the footprint, directly along the downlink antenna "boresight." It also explains why extremely large antennas, often in excess of 30-feet in diameter, are necessary for adequate reception of American satellites in countries such as Argentina, far off downlink antenna boresight.

Although published footprint maps are available for each satellite there is also some variation between transponders on any given satellite. Satellite TV dealers and enthusiasts know well which transponders on-board an older and somewhat weaker satellite such as Satcom III have the lowest power. In fact, if clear pictures can be received from the weakest transponders then a given earth station is performing well for its intended use.

Understanding Footprint Maps

Satellite footprint maps provide valuable information in sizing components of an earth receiving station. Power levels on these maps are termed effective isotropic radiated power, EIRP, a weighty sounding term. And EIRPs are measured in units called decibels above one watt (dBw). A footprint map is constructed by joining all those points on the map having equal EIRP by continuous lines. So a distinctive "footprint" is published for every orbiting satellite as a series of contour lines superimposed upon the map of that region served.

The decibel scale was devised by Alexander Graham Bell to describe the enormous changes in power at various stages of the communication chain by relatively small numbers. This was necessary because components like amplifiers and antennas could increase power levels many hundreds of thousands of times. So constantly writing out such numbers could have become very cumbersome. A useful fact to remember is that small changes in decibels mean relatively much larger changes in power levels. For example, a change of 3 dB means a doubling of power; a change of 30 dB means an increase of power by a factor of 1000. Note that dBw means decibels relative to one watt; dBm means decibels relative to one milliwatt. So by comparison with Table 1 below, 3dBw means 2 watts and 0dBm means 1 milliwatt (see Appendix A for more details on the decibel scale).

TABLE 1-4. THE DECIBEL NOTATION

Number of Decibels	Relative Increase in Power
0	1
1	1.26
3	2
10	10
20	100
30	1,000
50	100,000
100	10,000,000,000

Footprint maps that show small changes in decibel levels demonstrate how widely signal powers actually change. Remember that the signal strength on any footprint map is always highest right along the central axis of the downlink antenna. For example, Satcom I relayed 33 dBm to Anchorage, Alaska, roughly half that received in Denver, Colorado at 36 dBm because of the 3 dB difference in downlink antenna beam pattern.

Satellites broadcasting to a more limited geographical region have a footprint covering a smaller area. These "spot beams" have proportionately higher EIRPs than those of a satellite targeting a much larger area with either "hemispherical" or "global" beams because the same power is more concentrated. Footprint maps are clearly determined by both the shape and orientation of the downlink antenna as well as by the power generated by each transponder.

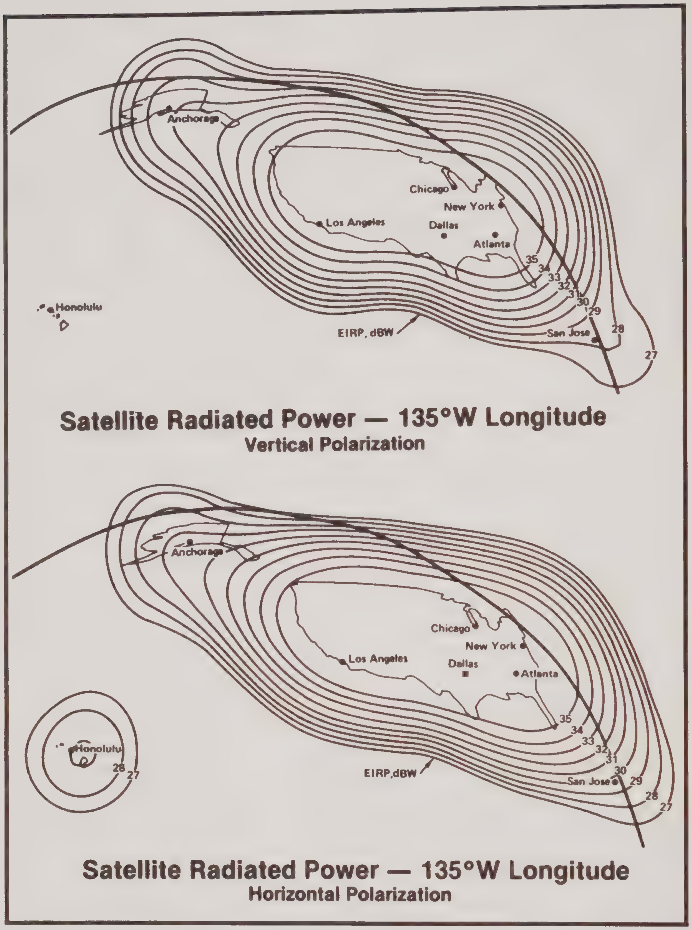


Figure 1-15. Galaxy I Footprint Map. *Points of equal received power are joined together to form a series of contours. Note that only the 12 transponders with horizontal polarization on the Galaxy I satellite are relayed to Hawaii in addition to the continental United States. (Courtesy of Hughes Communication, Inc.).*

Why are these power levels named effective isotropic radiated power? Isotropic means equal in all directions. And effective isotropic radiated power means the power levels that would be received at any location if an antenna were radiating equally in all directions. So 33 dBw read from a footprint map means that such a perfect antenna would direct 33dBw or 2000 watts per square meter in all directions.

EIRP levels are measured as those leaving the downlink antenna. In the above example, 2000 watts per square meter are directed towards that location on earth below. However, the signal leaving this satellite spreads out in a cone-like beam as it travels to the earth below. This weakening or dilution in power as it moves further and further away from the satellite is called the "free space path loss" or "spreading loss." The longer this distance, called the "slant range," the greater are the free space path losses.

Contributing to the losses incurred on the homeward voyage are absorption by molecules of the atmosphere. Water vapor is the main culprit in the attenuation of downlinked signals. In fact, during a severe rainstorm, the power received on the surface of the earth can be reduced by as much as 3 dB or 50% at higher Ku-band frequencies.

These free space path losses and atmospheric absorption explain why a transponder operating with only 5 to 9 watts total power that sends a signal via a downlink antenna into a beam of 2000 watts per square meter more is detected on earth at a strength of less than roughly one tenth of one billionth of a billionth of a watt per square meter! Note that detecting a 5 watt transponder is like seeing an average Christmas light bulb from a distance of 22,300 miles. Or it is like receiving a CB radio transmission, which is designed to have a 10 to 15 mile range, from 22,300 miles away. The C-band satellite broadcast operates at a frequency 131 times higher than CB radio.

Satellite Launching and Maintenance

The excellence of a satellite communication system depends upon launching long-lived vehicles into stable geosynchronous orbits. Since Sputnik's successful flight in 1957, man has been able to lift heavier and more sophisticated payloads into orbit. During the 1960's booster rockets were inadequate to position a satellite directly into the required geosynchronous orbit. As a result, extra rockets in the body of a telecommunication vehicle were used for repositioning it from its initial low circular orbit into its final geosynchronous position. The engine and fuel of the satellite then accounted for nearly half its total weight.

Today, similar techniques for boosting satellites into space are used even though current communication vehicles have greater masses and can be lifted into space by much more powerful crafts. Earlier Thor-Delta launch rockets have been replaced by more powerful boosters such as the Delta-2914, the Delta-3912 and the Atlas Centaur. The European Space Agency's Ariane rockets as well as the U.S. space shuttle now launch the lionshare of geosynchronous satellites.

Communication satellites would remain stationary forever above a chosen location over the equator if there were no extra gravitational forces from the sun and moon, if solar winds did not sweep past our globe, and if the earth were perfectly spherical. This is not the case, so these unbalanced forces cause any satellite to drift slowly away from its assigned location. There are, however, two "zero-pull" locations at approximately 104.5 degrees West and 75.5 degrees East on the exact opposite side of our globe where these forces balance so a geostationary body will remain stationary. The Canadian satellite Anik I, located at 104 degrees West is closest to the western hemisphere zero-pull location.

Figure 1-16. Footprint Map and Antenna Size. *Many footprint maps are drawn showing a minimum required antenna diameter instead of EIRP.*

Since all satellites to the west of 104.5 degrees West will drift towards the east and those located to the east of this point will drift westward, ground controllers periodically adjust satellite positions to counteract these forces. All communication vehicles are equipped with small hydrazine gas charged "thrusters" that are fired whenever necessary.

Satellite antennas and solar cell arrays must also be periodically realigned with their targets. In order to relay a beam having a width of approximately 4 degrees (as is typically required to cover the continental United States) towards a chosen location on the earth, downlink antennas must be accurately pointed within 0.2 degrees. This is very important because most satellites, even when accurately positioned, move in a small figure-eight pattern, usually about 15 miles across. Even this very small movement can impair reception of signals on earth by large, narrow view antennas.

Also, in some satellites the solar cells must also be accurately pointed towards the sun so that they will provide as much power as possible. Satellites are aligned, for both these reasons, by spinning their whole body in order to create a stabilizing gyroscopic effect similar to those forces that keep a rapidly spinning top upright. The improved stability of present-day vehicles permits use of larger antennas, capable of focusing higher-power microwaves and housing larger solar cell arrays to increase satellite power.

Figure 1-17. Westar IV and V Satellites. *These satellites built by Hughes Aircraft Company each have 24 transponders. The solar cells generate 800 watts of power over an estimated 10-year lifetime. (Courtesy of Hughes Aircraft Company).*

Satellites do not live forever. Their life expectancy is determined by how long adequate power and stability can be maintained. Repositioning rockets usually run out of hydrazine gas before surviving ten years in space. Also, solar cells, constantly bombarded with micrometeorites and ultraviolet rays from the sun, slowly wear out. Either a 30% reduction in solar cell power or expiration of the hydrazine fuel supply is a signal to retire a satellite from active duty. For example, Satcom III, the time-tested workhorse of broadcast satellite TV, will soon be decommissioned due to slowly decaying transponder powers. When ground controllers put a satellite to rest it is boosted into a slightly higher, unstable, nongeosynchronous orbit where, in time, it will eventually reenter the atmosphere and burn up. Recently, the space shuttle has recovered some damaged satellites. This manoever has saved 50 to 80 million dollars in hardware and launch costs and may someday be used to recapture and reuse satellites.

Future Trends in Satellite Design and Operation

Satellite technology is still in its infancy. The next decade should bring some rather incredible advances in design and operation of the space-based communication system. Some of these improvements will come in response to the need for additional orbital space, the most obvious move being the use of higher frequency bands.

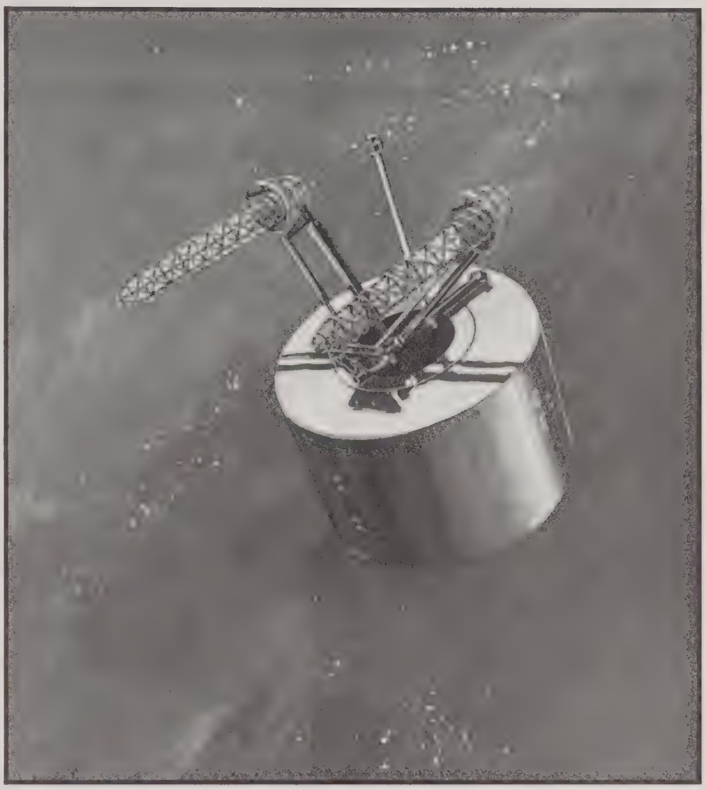


Figure 1-18. LEASAT Satellite. *First of the "widebody" satellites, the LEASATs are designed to take maximum advantage of the Space Shuttle's cargo hold capabilities. Each vehicle is 14 feet in diameter and 20 feet high with antennas fully deployed; the Shuttle's payload bay has a 15 foot diameter. (Courtesy of Hughes Aircraft Company).*

Satellites can be co-located in the geosynchronous arc if they operate in different frequency bands and can thus be effectively invisible to each other. Already some satellites, for example Spacenet I, have both C- and K-band transmitting antennas installed. Clusters of non-interfering, co-located satellites could be relayed information by just one uplink facility. In addition, all these vehicles could further conserve resources by sharing a single platform, positioning system and power supply. Such a rigid platform housing all the satellites would probably also improve the overall stability of the downlink antennas and could therefore enhance performance of each.

Satellite circuits could be used more effectively by employing communication directly between satellites with microwave or laser beams. This method works very well in outer space because there is no atmosphere to weaken signals bouncing between satellites. In fact, the FCC and ITU have already allocated frequency bands for intersatellite links. Using such relays could make communication between very distant countries less expensive by eliminating an intermediate link. For example, a message uplinked in San Francisco could be received by a American satellite, relayed directly to a one positioned over the Mediterranean and subsequently downlinked to Saudi Arabia. The alternative would be to use an intermediate Intelsat (International Telecommunications Consortium) satellite or a sub-

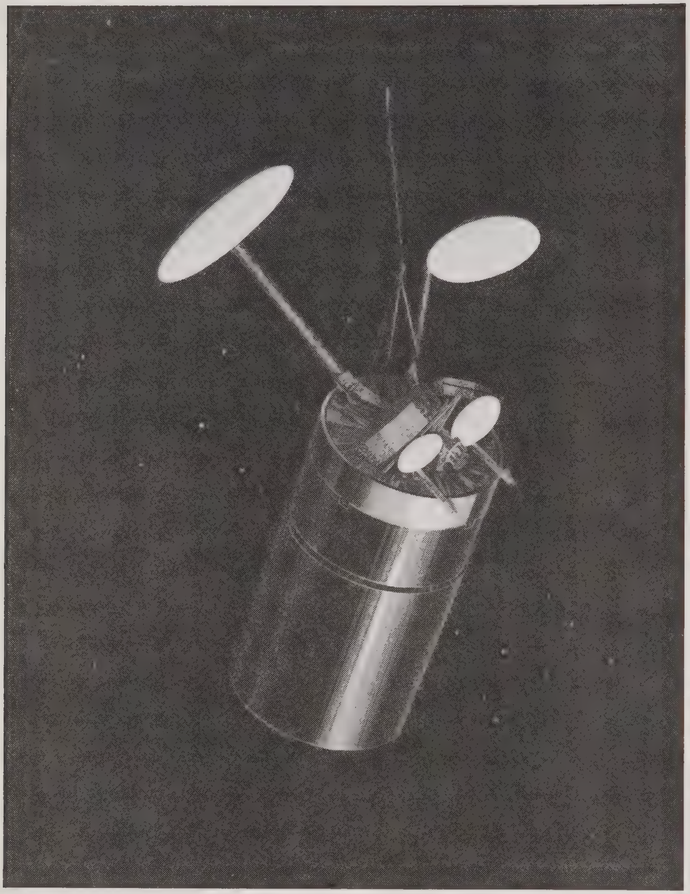


Figure 1-19. Intelsat VI. *This communication satellite stands nearly 39 feet high with its antennas upfolded and aft solar panel extended. (Courtesy of Hughes Aircraft Company).*

marine cable, which would probably increase the cost of communication.

Satellites could switch between differently targeted antennas on command or have moveable, narrowly aimed antennas called steerable spot beams to select from predefined footprints. This would allow its available allocated frequencies to be reused in different geographic regions. Such vehicles could employ the available power more effectively by restricting their output to limited areas and thus increase EIRPs. The first such vehicle on the drawing board is the European Space Agency's L-Sat platform satellite.

Other techniques under development involve using more efficient coding methods so, for example, one transponder could relay two or three instead of one television channel (see Satellites Today for more background detail on these subjects).

II. COMPONENT OPERATION

A. ANTENNAS

The earth station antenna is the eye on the sky. It must intercept and capture extremely weak radiation from a targeted satellite and concentrate it to a point (called the phase center) where the feedhorn is placed.

The quality of a satellite antenna, often simply called a "dish," is determined by how well the dish targets a satellite and concentrates the desired signal and by how well it ignores unwanted noise and interference. These seemingly simple design objectives have been the subject of a whole scientific and engineering discipline for many years.

Dishes must be durable and able to withstand winds and other natural or even man-made forces. In order to be able to compete in the marketplace, they also must be aesthetically pleasing and affordably priced. Ever since the October 1979 FCC decision which deregulated receive-only systems, many small and large businesses have tried their hands at realizing all these objectives.

Varieties of Antennas

Most microwave antennas used today in satellite earth receiving stations have designs based upon combinations of circular or parabolic surfaces, which are familiar geometrical shapes originally discovered by the ancient Greeks. Any microwaves reflected off these surfaces will be concentrated to a point or to a series of points called "focal points." (We will discuss these multi-focus dishes later.).

The most familiar dish, the prime-focus parabola, theoretically focuses all incoming signals directed parallel to its axis to a single point. Any signals arriving from a direction other than that of the targeted satellite will be reflected away from this focal point.

In practice, this dish will not behave as expected by theory for three reasons. First, the equipment mounted at the antenna focus is

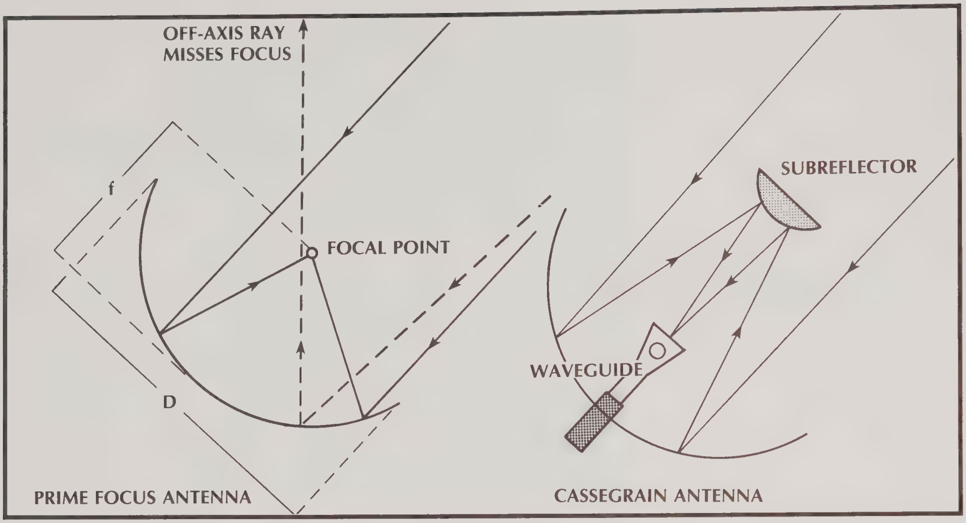


Figure 2-1. Prime Focus and Cassegrain Antenna Geometry. *Signals are reflected from the dish surface to a focal point. Off-axis rays will miss this focal point. The Cassegrain antenna uses a second reflector to direct microwaves to a feed located behind the reflector surfaces.*

spread around the focal point so that it will intercept some microwaves from directions slightly off target. Second, irregularities in the surface shape will cause errors so that some off-axis signals are detected and some targeted signals pass by unobserved. Third, dishes simply do not behave as perfectly as ray-tracing geometry would dictate because the radiation they intercept behaves according to principles of waves and some spreading around the edges occurs.

The Cassegrain antenna also has a parabolic surface but redirects radiation via a second reflective surface (called a hyperbolic subreflector) down a waveguide to an LNA behind the dish. This type of dish is often more expensive than the ordinary prime-focus one and is more often found in commercial installations. But in hot climates, earth station using Cassegrains can perform more effectively because the LNA is located behind the antenna and is protected from the direct sun's rays.

There are other less familar antennas. The horn reflector, shaped like a horn, sends intercepted signals entering via a large aperture down the reflective body of the horn to a focus. So the whole body of the horn performs the same function as the feedhorn does for a prime-focus dish or Cassegrain antenna.

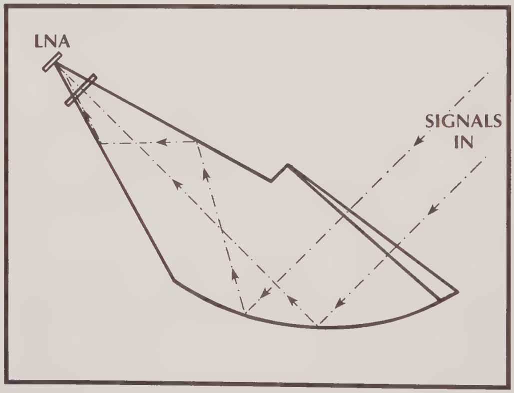


Figure 2-2. Horn Antenna. *This type of antenna geometry is very effective in capturing microwave signals. It is an expensive variety often used on line-of-sight relay towers.*

An "offset feed" antenna can be constructed by taking a section from a large prime-focus parabola. The feed assembly which is still at the focus of the larger antenna is offset from the portion of the reflective surface used. In this position, it is not in the way of any incoming signals.

Judging Dish Performance

Dish performance is judged by a number of interrelated factors including gain and efficiency, beamwidth, side lobes, noise temperature and f/D ratio. Unfortunately, many dish manufacturers either do not have the facilities or the desire to measure some of these performance factors. So, word of mouth opinions are often the criteria used to judge home satellite systems. However, until a low cost, independent testing organization is established, dealers can still evaluate dishes quite effectively knowing the underlying theory and understanding how antennas are designed and manufactured.

Figure 2-3. Offset Fed Dish. *The feed of this dish is located at the focal point of a large prime focus antenna from which this smaller section of reflector actually used is taken. Note that a specially designed feed sees signals reflected from only that portion of the larger parabola used. (Courtesy of Comtech Antenna Corporation).*

Antenna Gain

Antenna gain, G, expresses how much of the intercepted microwaves are concentrated towards the feedhorn. Gain is dependent upon three factors. First, as dish size increases, more radiation can be intercepted so gain also increases. Therefore, if the area of an antenna is doubled so is the gain. For example, a 12-footer has 44% more gain than a 10-footer because the area increases with the square of the diameter ($12 \times 12 = 144$ compared to $10 \times 10 = 100$).

Second, gain increases with frequency. Higher frequency microwaves do not spread out as would waves in water but are more easily focused into straight lines like beams of light. This is one reason that Ku-band broadcasts (also known as DBS, direct broadcast systems) which operate at 12 GHz instead of 4 GHz are capable of being captured by smaller dishes.

Third, gain is determined by how accurately the surface of an antenna is manufactured to exactly its designed shape. Even small distortions in the surface of a dish can cause substantial amounts of signal to be lost (see Table 2-1). Therefore, a dish that has ripples in its surface will behave more poorly than one that is smooth and is closer to its designed shape, especially at the higher frequency Ku-band.

TABLE 2-1. LOSS OF GAIN WITH SURFACE DISTORTION (C-Band Microwaves)

Average Surface Distortion (inches)	Loss of Gain (percent)
0.01	0.2
0.05	1.7
0.10	4.4
0.25	28.8

Antenna Efficiency

Antenna efficiency is a measure of how much signal is actually captured by the dish and feedhorn/LNA assembly. If it were possible, a dish having a 100% efficiency would therefore direct all the power intercepted from a broadcast satellite into the feedhorn.

Efficiency is determined by the surface accuracy of the antenna, by losses that occur when microwaves are not perfectly reflected but absorbed by its surface, by reflective losses off of components sited in the path of the incoming rays such as the feedhorn and its supports, and by something called "spillover" which we will examine in the section on feedhorns.

Typical efficiencies range from lows of 40% for quite poorly designed systems to 65% or even 70% for high quality antennas. Offset fed parabolas can have efficiencies in excess of 80% because there are no structures between the incoming signal and the dish surface to reflect away the energy.

Antenna gains ranging from the theoretical maximum (100% efficiency) to those for dishes having efficiencies as low as 50% are shown in Table 2-2 :

TABLE 2-2. ANTENNA GAIN IN DECIBELS AT 3.95 GHz

ANTENNA DIAMETER (feet)	ANTENNA EFFICIENCY 100%	80%	70%	60%	50%
5.0	36.18	35.21	34.63	33.96	33.17
6.0	37.76	36.79	36.21	35.54	34.75
7.0	39.10	38.13	37.55	36.88	36.09
7.5	39.70	38.73	38.15	37.48	36.69
8.0	40.26	39.29	38.71	38.04	37.25
8.5	40.79	39.82	39.24	38.57	37.78
9.0	41.28	39.34	39.73	39.06	38.27
9.5	41.75	40.78	40.20	39.53	38.74
10.0	42.20	41.23	40.65	39.98	39.19
10.5	42.62	41.65	41.07	40.40	39.61
11.0	43.03	42.06	41.48	40.81	40.02
12.0	43.78	42.81	42.23	41.56	40.77

When reading this table remember that a 3 dB difference means a doubling of gain; 1 dB means a 26% difference; and 0.1 dB means a 2.3% difference. Small decibel changes mean large variations in performance. Also, those numbers for 50% efficient dishes are not half those for 100% ones because these are expressed in decibels, not the raw signal concentration factors. So, for example, a perfectly efficient 5 foot dish concentrates signals by a factor of 4,150 times (36.18 dB); one with a 50% efficiency by 2,075 times (33.17 dB, the number of decibels in 50% of a 4,150 signal concentration or half the power).

Beamwidth and Side Lobes

Antenna beamwidth and side lobes determine what a dish actually "sees." If a dish were set up on a test range and a microwave source was rotated across its field of view, the captured power plotted against this angle would give all the necessary information about beamwidth and side lobes. A plot of beamwidth is shown in Figure 2-4. It is, in essence, a "fingerprint" of dish/feed quality and performance.

The beamwidth of a dish is a measure of how well it can target a very narrow region of space. This is a very important factor because satellites separated by 4 degrees or less and located more than 22,300 miles away appear to be very close together. Most of the received power is contained in the main lobe. The beamwidth is defined as the width of this main lobe between the "half power" points where power has dropped by 50% or 3 decibels.

The beamwidth indicates how well a dish will detect off-axis radiation. For example, if the beamwidth is 2.4°, then each side of the beam at 1.2° will be able to capture signals at half the power of those entering the dish on the main axis. If an adjacent satellite happened to be located at 1.0° away from the targeted one this interfering signal would be received nearly as well and result in a unacceptably noisy picture.

The side lobes also determine how capable a dish is of seeing radiation coming from off-axis directions. Side lobes must be substantially lower in their ability to receive power. If this is the case, for example, a signal of 1 watt which might be detected in full by the main lobe could be reduced by 20 decibels when it is located 2 degrees off-center and seen by a side lobe. If this were not the case, a dish having a side lobe 2 degrees away from the main lobe reduced only slightly in power could see too much of those signals from another satellite spaced 2 degrees away from the targeted vehicle.

If the power levels of the side lobes are 20 dB or more below those of the main lobe, then a dish can perform excellently. If side lobes are more than 3 or 4 degrees away from the main lobe and reduced in power by less than 10 decibels there is trouble. Watching channel 4 and the messy interference between these two signals coming simultaneously from two adjacent satellites will be very annoying.

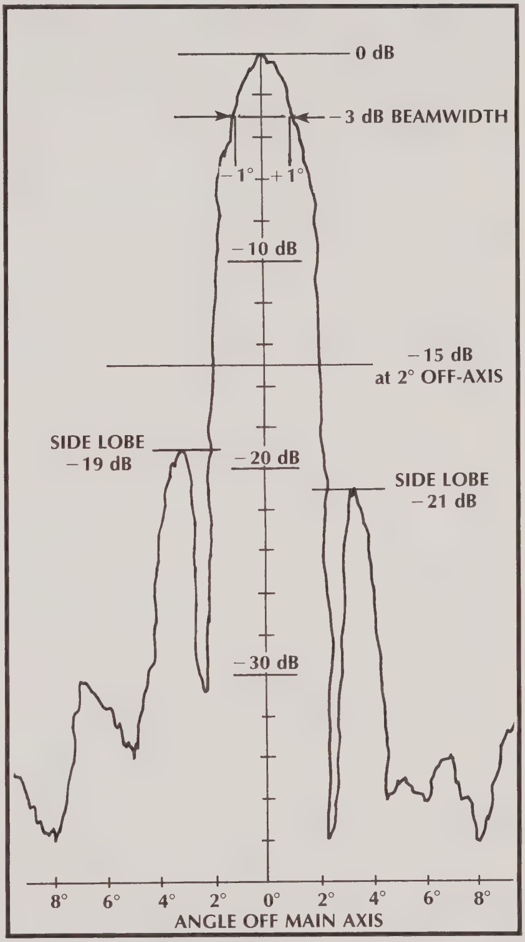


Figure 2-4. Antenna Lobe Patterns. *This graph shows what relative power levels a typical 10-foot dish detects away from its boresight or axis. The taller and more narrow the central portion is relative to the side lobes, the better will an antenna target a pinpoint in the sky. In this case, the 3 dB beamwidth is 2° and the side lobes are located at 3° on either side of the main axis. Signals coming in at 2° are reduced 15 dB relative to those received along the boresight.*

This characteristic "fingerprint" depends upon a number of factors, among the most important being reflector surface accuracy. The width of the main lobe, called the beamwidth, decreases as both the frequency of the satellite message and the antenna diameter increase. A 10-foot dish will have half the beamwidth as a comparable 5-footer. A Ku-band transmission will be received with one third the beamwidth as a C-band broadcast (12 GHz divided by 4 GHz equals a three to one decrease in beamwidth).

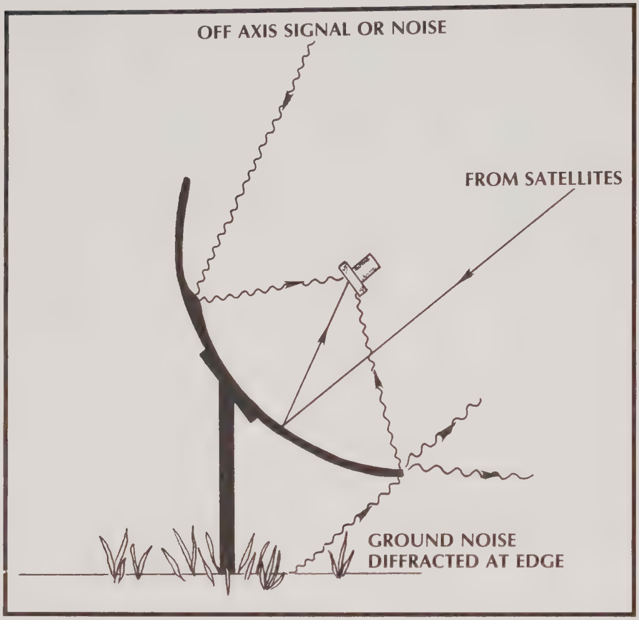


Figure 2-5. Spillover and Antenna Vision. *This schematic shows how a dish can actually detect microwaves from behind. Noise from the warm ground is diffracted by the dish edges and scattered in all directions. Some of this manages to enter the feedhorn. Side lobes can also be increased by reflector surface irregularities causing off-target signals to be detected.*

Side lobes are an inherent property of the wave-like character of microwaves and the resulting "spreading" in the vision of an antenna. This "spillover" results when microwaves strike the edges on the rim of an antenna and are bent (as a result of diffraction and interference, well-known effects from optics). Spillover causes dishes to have the rather astonishing ability to detect radiation coming from directly behind them. Every dish has a theoretical lobe pattern showing how power from the full circle around the antenna will be detected. Of course, the ability to pick up power coming from behind a dish is much lower than that detected in front of the antenna along the main axis.

These theoretical patterns are affected by other real-world design considerations. The most important influences on lobe patterns are unwanted reflections off of the feed and its supporting structure and by stray signals caused by inaccuracies in the antenna surface. Note that offset fed dishes can potentially have lower side lobes because the feed assembly is not in the path of incoming signals.

The difference between an excellent and a poor-quality antenna is easily seen in their lobe patterns. Manufacturers publishing this information do a service to the industry. It is important to understand that apparently small changes in design can effect the "vision" of a dish. For example, even if square and round prime-focus antennas cut from identical larger dishes have the same surface areas and gains, they may have quite different lobe patterns.

Antenna Noise

Noise temperature is a measure of how much noise an antenna "sees" coming from the surrounding environment and outer space. It obviously depends upon the lobe pattern which determine the ability of a dish to ignore random noise coming from the surrounding warm

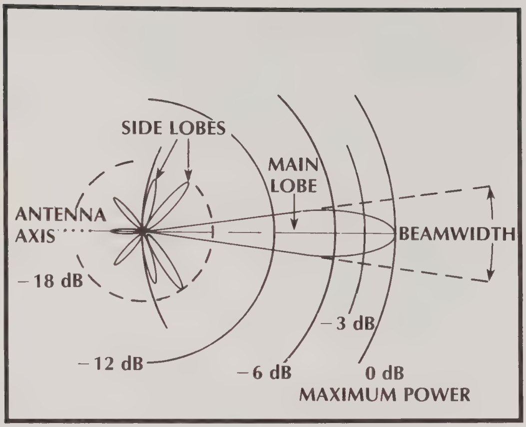


Figure 2-6. Calculated Antenna Lobe Patterns. *Although most of the radiation detected is concentrated in the main lobe, this calculated pattern shows that some noise can be detected from a full circle around an antenna.*

ground. Noise comes from both man-made sources such as florescent lights which emit microwave radiation and natural sources such as the surrounding terrain. In general, it is the natural, higher frequency sources of noise which are the predominant cause of detected noise power in satellite TV systems.

Since the warm ground emits radiation, noise temperature increases as a dish is pointed at a lower and lower elevation angle in regions further from the equator. A set of curves showing how much noise is added as elevation is decreased is presented in Figure 2-7. Note that larger antennas detect less noise because they have smaller side lobes.

Focal Length to Antenna Diameter Ratio

The focal length to antenna diameter ratio, the f/D, is also an important parameter in characterizing a dish. In general, if the f/D is lower, the side lobes will be smaller all else being equal. This is because the feed/LNA structure is closer in to the reflective surface and therefore is better screened from the surrounding environment. A similar but not equal result (because side lobes will differ) can be obtained if a reflective shroud is affixed around the rim of a dish. This is just like putting blinders on a horse so it will see only in one direction, straight ahead.

The f/D is used to classify dishes as either deep, average or shallow. In general, a f/D less than 0.3 defines a deep dish; one in excess of 0.45 defines a shallow dish. (Offset fed configurations generally must be used with rather shallow dishes to work adequately.). Note that deeper dishes are generally less susceptible to environmental noise and usually have lower side lobes and lower noise temperatures.

Dish Construction

Dishes can be made from a variety of materials and by numerous manufacturing processes as long as they meet basic requirements. They must adhere to their designed shape over a long period of time, have metal in their surface in order to reflect microwaves, be easy to assemble and be shippable at a reasonably low cost.

The details of design, materials selection and manufacturing are very important. An antenna may perform well when new but, in time, after being subjected to environmental stresses its performance and quality may seriously degrade. Allowances must be made for contraction and expansion of different materials with changes in temperature, for wind loading, for rain, snow and hail, for the effects of intense sunlight, and for many other factors. Remember, the dish is the eyes of a satellite receiving system and a critical component needed for quality performance.

There are four major classes of dishes: spun aluminum or steel; stamped or drawn steel; fiberglass; and expanded metal or mesh.

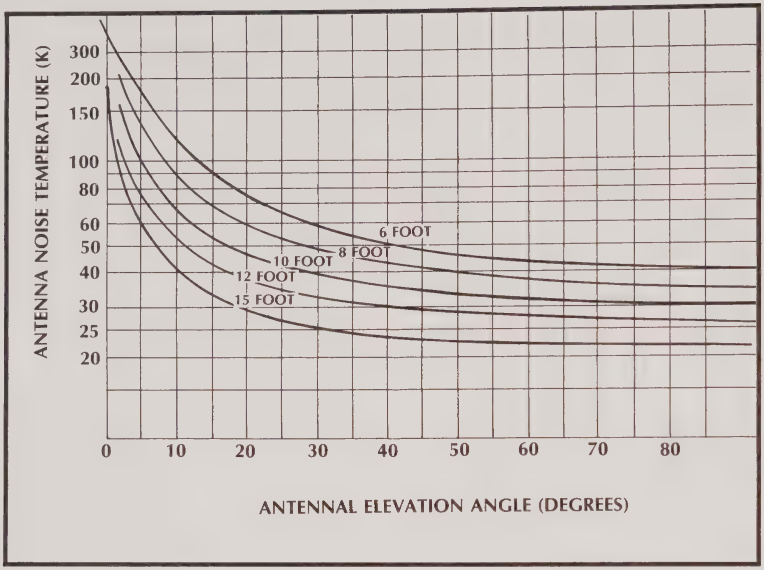
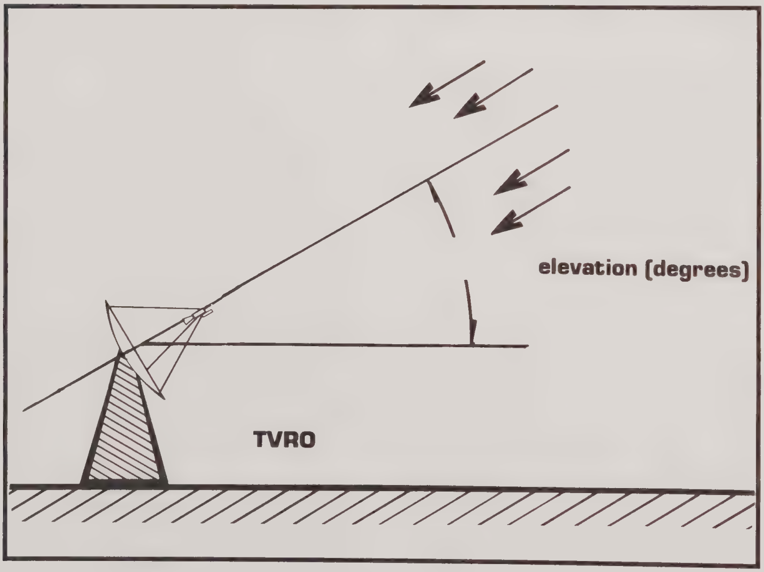


Figure 2-7. Antenna Noise Temperature. *The lower an antenna is pointed towards the ground, the more noise it is capable of detecting. (Top illustration courtesy of the Microwave Filter Company).*



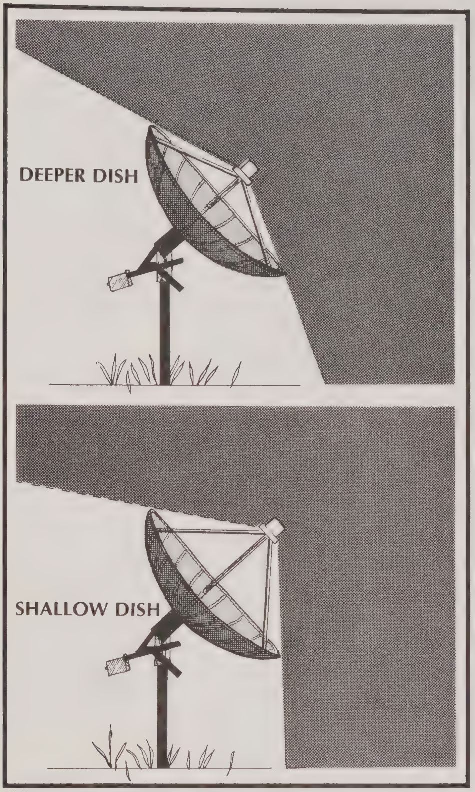


Figure 2-8. f/D and Field of View. *Dishes with a smaller f/D have a more narrow field of view, can be less susceptible to noise and interference, and can have smaller side lobes.*

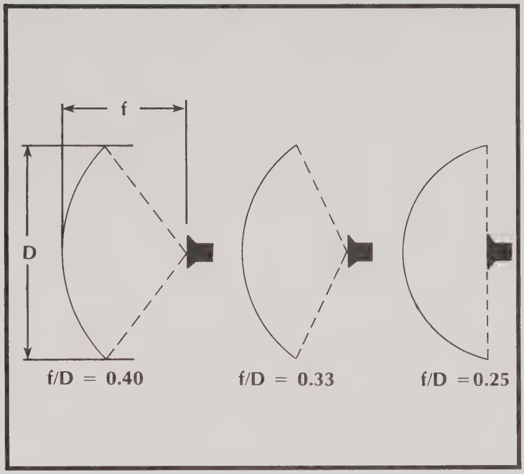


Figure 2-9. Focal Length to Antenna Diameter. *A lower f/D means that the feed assembly is closer to the reflective surface. At a 0.25 f/D, the feed is in a line with the dish edge and adequately illuminating the entire reflector surface becomes difficult.*

Spinning

Spun aluminum or drawn steel dishes tend to have the most accurate surfaces. They are manufactured by mounting aluminum or steel, typically of 0.080 inch thickness, on a die and spinning the whole assembly while pressing it into shape with rollers. When done correctly, it results in a highly accurate dish with a metal surface hardened by the manufacturing process. This method also has the advantage that several different size antennas can be made from one mold, each diameter having a different f/D ratio.

Spun dishes come in one piece and can be difficult to ship. Some spun dishes are made with perforated metal, metal which has had holes punched into it. In general, if the holes are less than one tenth of the wavelength used (less than 3/10ths of an inch for C-band radiation) losses through the holes are negligible.

Stamping or Hydro Forming

Stamped or drawn steel dishes are similar in design to hydroform processed devices. They are made by stamping or pressing flat sheet metal into shape. The hydroformed process uses water to aid in creating a smooth reflector surface. A good quality dish can be produced by these methods at a relatively low per unit price. However, the required tooling can be expensive and only one size dish is produced for each mold.

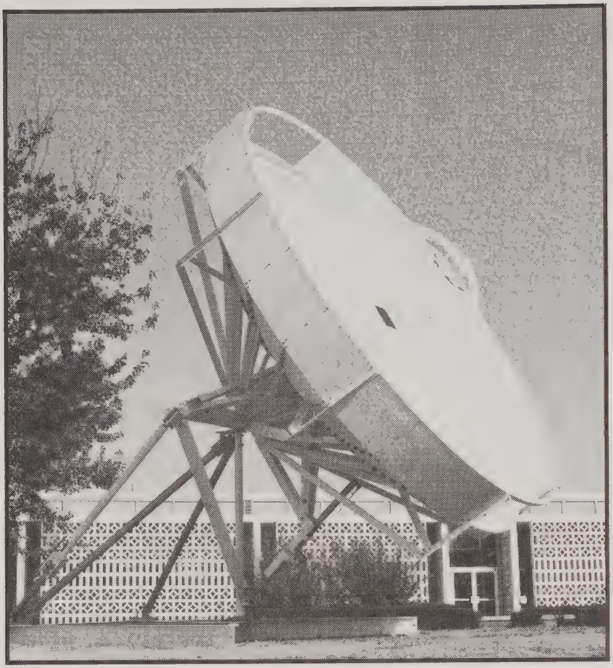


Figure 2-10. Cassegrain Antenna with Protective Skirt. *The rim aids in shielding the dish from unwanted noise and interference. Note that the skirt should be made from a material that absorbs but does not reflect microwaves. (Courtesy of Scientific Atlanta, Inc.).*

Figure 2-11. Spun Aluminum Dish. *(Courtesy of Birdview Corporation).*

Fiberglass

The challenge of manufacturing a fiberglass antenna is to embed wire screen, aluminized mats or other metallic materials in the fiberglass resin while retaining an accurate surface shape. Fiberglass dishes are manufactured by three methods. In the hand layering or laminating process, a fiberglass resin called gelco is smeared onto fiberglass cloth laid in a mold. This gelco has pigment to give the dish color and inhibitors to protect against ultraviolet damage from intense sunlight. Metal is flame sprayed onto the dish. This results in a strong, lightweight but relatively expensive dish.

In sheet-molding, a mixture of polyester resin, calcium carbonate and chopped fiberglass strands are mixed together and then pressed onto a metal screen. The resulting product is lightweight but usually brittle and easily damaged.

In thermal injection molding, the mat and screen are set into a closed mold and resin is injected under pressure. Dishes manufactured by this process are strong, impact-resistant and usually have good cosmetics but still require shipping by truck.

Wire Mesh or Expanded Metal

The fourth type of antennas are made from wire mesh or expanded metal. These are held together by a rib structure which can be time consuming in assembling. This mesh can be attached to its supporting structure by a series of clips or by insertion into a channel in an extrusion. Such dishes

are popular because of their asthetic appeal, light weight and lower wind resistance but can be flimsy if not designed correctly. Perforated metals can be either made into one piece dishes by spinning or stamping but can also be used as the petals for mesh-type antennas.

Making the Choice

Judging which type of dish to use is based upon many factors including aesthetics, performance, weight, ease of assembly, wind loading, durability, ease of shipping and cost. For example, spun aluminum dishes can have excellent surface accuracies but come in one piece and are not easily shipped. Wire mesh dishes which many find very attractive can be broken down and shipped in small boxes but may conform to a parabolic shape less accurately than other types if the panels are not held securely. Stamped aluminum dishes are very durable if their wall thickness is sufficient but are more easily buffeted by winds than a wire mesh antenna.

Remember that microwave antennas are also capable of performing as solar concentrators. So the choice of colors and surfaces can be critical. A brightly painted dish or a smooth metal surface can reflect enough solar energy to melt Polarotor® caps or fry cables. When painting an antenna, an optically rough paint must be used so that the sun's rays are scattered not focused to generate heat. It is also better to use paints which are non-metallic since rough spots or bumps in the coat could cause reflection errors.

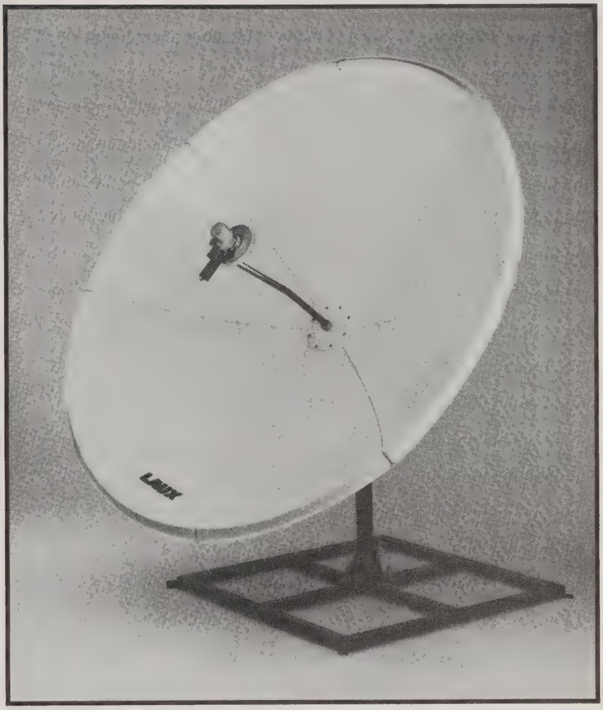


Figure 2-12. Stamped Metal Dish. *(Courtesy of Laux Communications, Inc.).*

Figure 2-13. Fiberglass Dish. *(Courtesy of M/A COM, Inc.).*

Wind Loading

In regions such as Wyoming or Colorado where winds often have speeds in excess of 60 miles per hour, wind loading is an important consideration. For example, a 10-foot dish experiences a force of approximately 2000 pounds when facing into a 65 mile per hour wind. Wire mesh dishes are subjected to smaller forces especially at velocities less than approximately 30 miles per hour. At higher wind speeds, they tend to be more like solid surfaces even though they still experience approximately a 40% lower force. An approximate wind loading chart is shown in Table 2-3 below:

TABLE 2-3. ANTENNA WIND LOADING
(Pounds of Torque)

	Wind Speed (mph)			
Antenna Diameter	25	50	75	100
6	40	170	400	700
8	200	400	900	1600
10	200	800	1800	3200
12	350	1400	3000	5500
14	550	2200	5000	9000
16	800	3300	7000	13000

Multi-focus Antennas

Multi-focus dishes were developed to allow more than one satellite to be simultaneously detected by a fixed antenna. In contrast, most single-focus dish are repositioned by actuators to receive signals from each satellite.

Commonly encountered multi-focus antennas incorporate variations of spherical and parabolic surfaces. In all cases, these dishes are aimed at the arc of satellites, and the reflected signals from each space vehicle are focused to a series of feedhorns. To illustrate, the Simulsat antenna, cut from a rectangular section of a sphere with feedhorns mounted in a long box at the focal line, was designed to simultaneously detect up to twenty satellites within a 57 degree arc. It did not function as well as expected. Another example is the Torus antenna, which is a dual-curvature reflector having a circular contour in the scan plane and a parabolic contour at right angles.

A standard prime-focus parabolic dish can also be used in an offset fed configuration where one or two extra feedhorns and LNAs are located on either side of the central feed. The reception of signals is not as "clean" because reflections from different parts of the antenna travel slightly different distances to reach these additional feeds (as is the case with all multi-focus dishes). This performance decrease can be partially overcome by using a slightly larger reflector. So an antenna of 12 to 16 feet diameter can then be capable of simultaneously seeing more than one satellite with minimum degradation of performance.

Such multi-focus antennas are almost always found in commercial installations such as cable TV company headends or apartment complexes. They are still a curiosity for home market dealers.

Figure 2-14. Wire Mesh Dish. *This 9 foot dish is assembled from 18 mesh petals and comes with either a linear or horizon-to-horizon mount. (Courtesy of GeoTrac Corporation).*

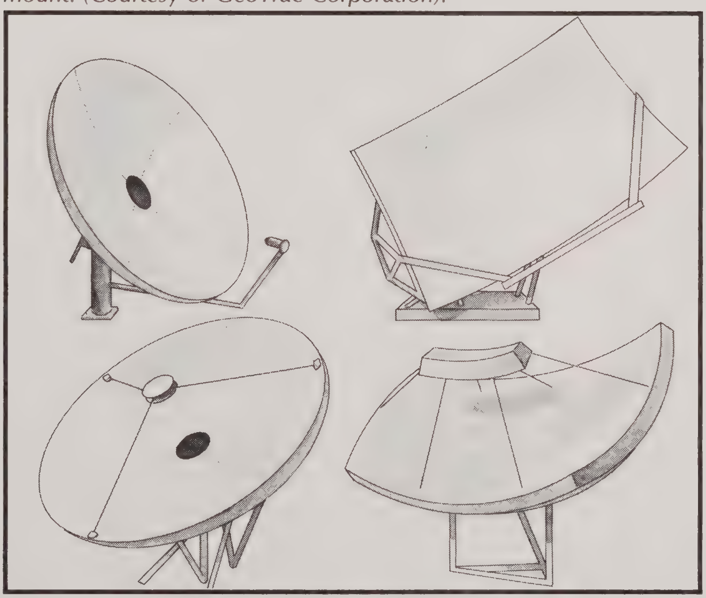


Figure 2-15. Multi-focus Antennas. *Multi-focus antennas are capable of simultaneously receiving signals from more than one satellite.*

B. MOUNTS

The purpose of an antenna mount is to target a dish accurately onto any chosen satellite and to permit aiming at any other satellite in the geosynchronous arc when desired.

Using a mount that provides stability and pointing accuracy is a critical part of designing and installing an earth station because well-designed dishes with narrow beamwidths target very small portions of the sky. For example, a dish with a 1.7 degree beamwidth (as is typical of a 10-footer) sees only one in fifteen thousands (1 in 15,000) of the visible sky. A 1/10th degree movement of a dish causes it to see a sweep of 45 miles at the geosynchronous arc (see Table 2-4 below). So the signal from a satellite would be reduced in strength if a dish moved even a relatively small distance off target. Without an adequate mount, such movement is possible when winds blow across the large sail-like, surface areas of an antennna.

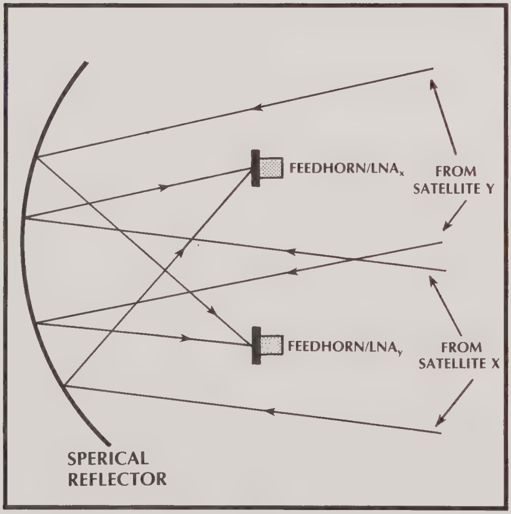


Figure 2-16. A Circular Multi-Focus Dish. *A circular reflector can be used to simultaneously view two or more satellites. This antenna should be at least 12 feet or more in diameter to compensate for the lower gain resulting from rays being reflected to a focal area not a focal point.*

TABLE 2-4. DISTANCE BETWEEEN SATELLITES

Spacing in Degrees	Separation in Miles
1	459
2	918
3	1377
4	1836

Mounts must therefore be strong and rigid and must be firmly attached to both the dish and the underlying structures. They are usually set on ground poles affixed in concrete pads or other supporting structures. Securing the assembly on the ground in a protected area is a much safer bet than having a dish on a long pole or roof mount where it must be able to resist strong, unlifting winds.

The design of the dish/mount attachment is very important. Since the mount assembly must be securely bolted onto a dish, any mismatch can cause stresses and possibly antenna warpage. This would result in increased side lobes and poorer performance. Fiberglass or a thin-walled metal will bend when placed under such stress. The points of attachment must be properly located and sufficient in number to evenly distribute the weight both in static and wind load conditions and to prevent dish warpage under these loads. And the mount must be strong enough to bear all the forces including,

in some geographic areas, potentially massive ice and snow build-up. The method for securing the mount to the support pole must be adequate to prevent twisting away from the north-south setting. Such collars can be very solid structures on some well-designed mount assemblies. Finally the points of attachment which support tracking movements must be designed with ball-bearings, brushings or other devices to prevent excessive wear over time.

Figure 2-17. The Torus Multi-Focus Antenna. *This antenna has a circular contour in the scan plan and a parabolic contour at right angles to this plane. All necessary feedhorns and LNAs are offset to the side. (Courtesy of SatCom Technologies, Inc., an RSI Company.).*

Types of Mounts

There are two major classes of mounts: those that track the arc with two movements or degrees of freedom like azimuth-elevation (az-el) mounts; and those that require only one movement like polar mounts.

Polar Mounts

Polar mounts rotate around an axis, the polar axis, aligned parallel with a line passing through the north and south poles of the earth. The mount is adjusted by setting the polar axis angle and the declination offset angle. The polar axis angle is set equal to the site latitude. To illustrate, in Denver located at 40 degrees latitude, this angle would be set at 40 degrees. At the equator, the polar axis angle would be set to zero degrees and the arc of satellites would be followed along a circle directly above. At both these locations, this setting would point the polar axis exactly along a north/south line.

The declination offset angle which ranges from 3 to 7 degrees in the continental United States, adjusts the tracking motion from a circle to a flattened ellipse. It compensates for the fact that the arc of satellites is at a finite distance; the further away this arc would be the smaller would be the required declination offset. Another way of visualizing this is by realizing that once the polar axis angle is set, a dish points directly along a line parallel to the plane passing through the earth's equator. The declination offset adjustment lowers the antenna's view to the arc of satellites. It should be set to the calculated value for that latitude during installation and, if held securely in place by the mount hardware, need never be touched again.

Polar mounts always have a small tracking error. If a satellite in the center of its sweep is

accurately targeted then those at the far ends will be slightly missed. If the end satellites are down the satellite boresight the central ones will be slightly off target. There is no way to avoid this inaccuracy. A properly set declination offset adjustment, however, has a tracking error of less than 0.1 degrees and allows a polar mount to sweep quite closely to all satellites from east to west. Tracking accuracy is especially critical when aiming at higher frequency, Ku-band satellites.

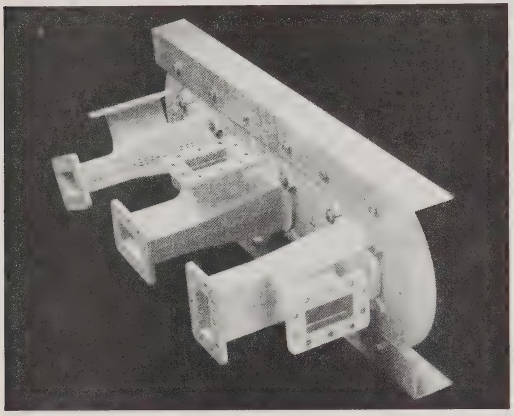


Figure 2-18. Multi-Focus Antenna Feed. *This feedhorn coupled with six LNAs is capable of detecting three satellites simultaneously. A dish of at least 12 to 14 feet in diameter must be used to properly receive the downlinked signals. (Courtesy of Seavey Engineering).*

Az-el Mounts

An az-el mount is much simpler to understand but more difficult to operate. A satellite is located by first moving to the correct azimuth angle, which is along the surface of the earth, and then rotating up to the required elevation angle. Such mounts are finding common use in motor homes and recreation vehicles because even though the base of the mount often sits at a random angle, the az-el mount has the ability to compensate by hunting in two directions. There is no tracking error so each satellite can be accurately targeted but more complex control devices are required to adjust both axis.

Az-el mounts were historically used in commercial systems and in out-of-footprint locations where a much larger dish was required because they are easier to install and usually stronger than polar mounts. The process of aligning a polar mount by fine tuning the north-south orientation can be quite cumbersome with massive, large antennas. However, today most of the newer large antennas are controlled by polar mounts (see Chapter VI).

Tracking Non-Geosynchronous Satellites

There are numerous satellites which have been launched into elliptical orbits. Many of these non-geosynchronous satellites are for military purposes and are, by their nature, classified but some broadcast entertainment and information. Mounts for tracking these moving targets must have two axes of motion like the az-el devices.

The Soviet Union's Orbita system based upon the Molniya satellites is a case in point. Since 1965 over 100 such vehicles have been launched; 12 are currently in service providing three independent full-time programming networks. Four equally spaced vehicles serve each network. Their unusual orbits leave them over far northern Canada for periods of 6 hours per day so tracking 24 hours per day requires that a different satellite must be locked onto every 6 hours. This tracking has been accomplished by sophisticated, computerized mounts but home TVRO systems have also been used by innovative operators to view this unusual television.

The Soviets have used such a system primarily because the look angle from their far northerly territories to the geosynchronous arc can be as low as 1 or 2 degrees making reception very difficult. Today other nations, such as Great Britian, are examining such communication methods for relaying cellular telephone.

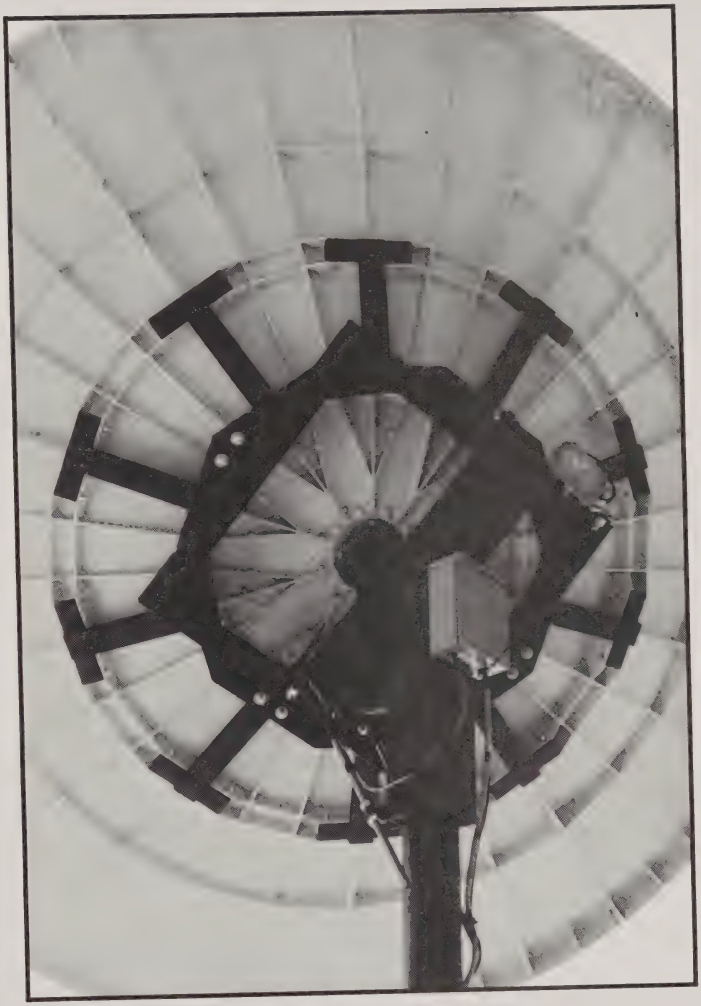


Figure 2-19. Prodelin Antenna Mount. *The mount on this Prodelin fiberglass antenna is solidly attached to the dish petals. (Courtesy of Echosphere Corporation).*

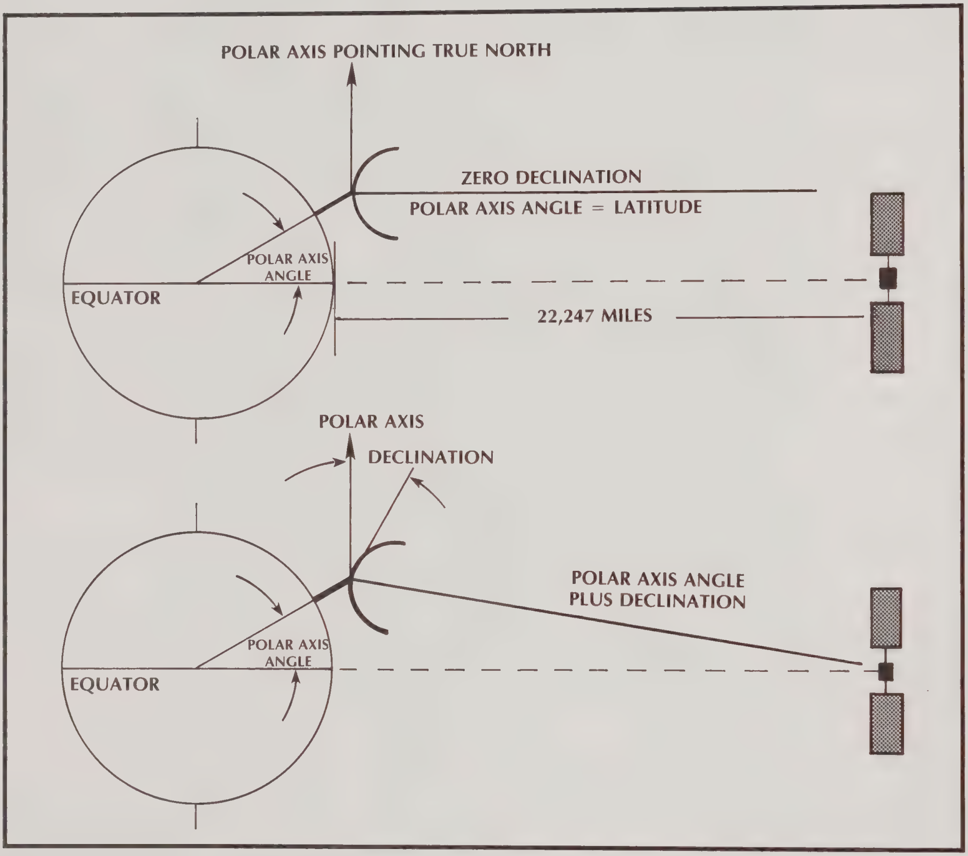


Figure 2-20. Alignment of a Polar Mount. *The polar axis angle set equal to the latitude points a dish along a plane parallel to one through the equator. Setting the declination offset angle lowers the field of view to the geosynchronous arc of satellites.*

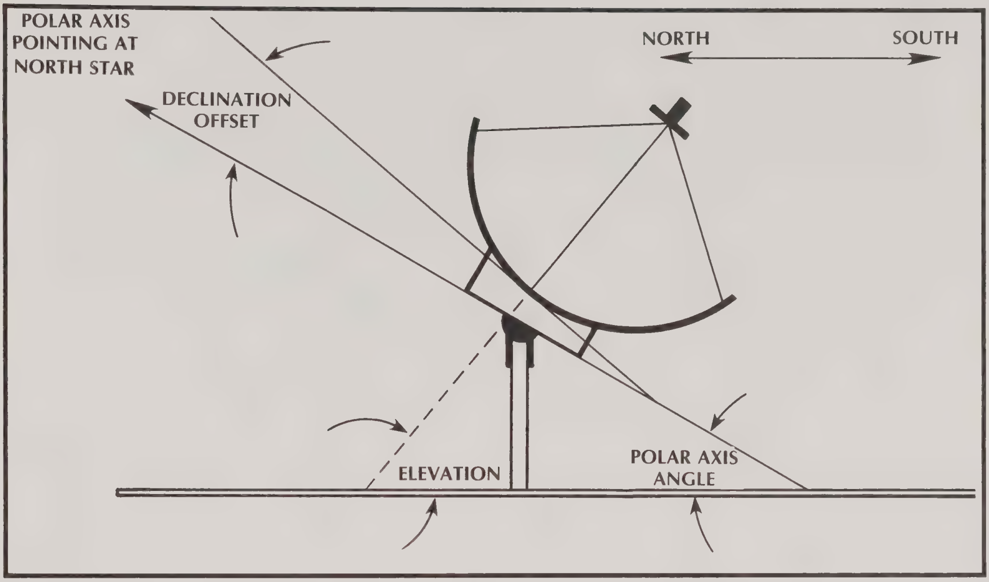


Figure 2-21. Polar Mount Geometry. *This close-up of a polar mount shows the details of setting the polar axis and declination offset angles.*

C. ACTUATORS

Actuators provide the mechanical drive and control to allow a dish to scan the arc of satellites. Just a few years ago when there were only a limited number of broadcast satellites most dishes were either fixed on one or hand-cranked between satellites. (Note that most antennas at cable TV headends are still fixed in one position.).

Today, most home satellite TV installations feature a motor-driven, worm-gear assembly which attaches between an arm on the antenna and one on the mount. Horizon-to-horizon mounts are also rapidly becoming popular. These have the gear mechanism encased at the support point of the dish and have the ability to track satellites across the whole visible sky, from one horizon to the other. This is becoming more important as additional satellites near the far reaches of the arc are being launched into orbit. Az-el mount actuators have two gear driven motors for adjusting azimuth and elevation.

Monitoring Dish Position

Earlier actuators had very simple customer interfaces. An east or west button or a switch would make or break a DC voltage relay to a motor to move the gear assembly and dish. Position would be maintained by the unit's internal brake assembly. When some customers damaged their actuators and sometimes their antennas by inadvertently driving motors past mechanical limits, programmable east and west electronic limits were introduced. However, programmable drives which sometimes "forget" their east/west limits have also damaged actuator jacks.

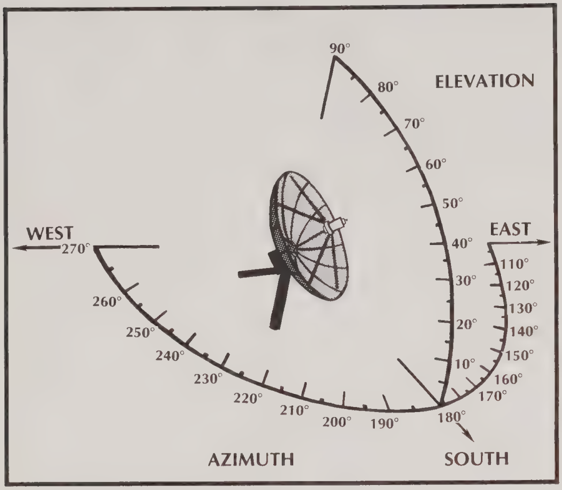


Figure 2-22. Az-El Mount Geometry. *The azimuth angle adjustment rotates a dish in a horizontal plane. The elevation angle adjustment raises a dish above the horizon.*

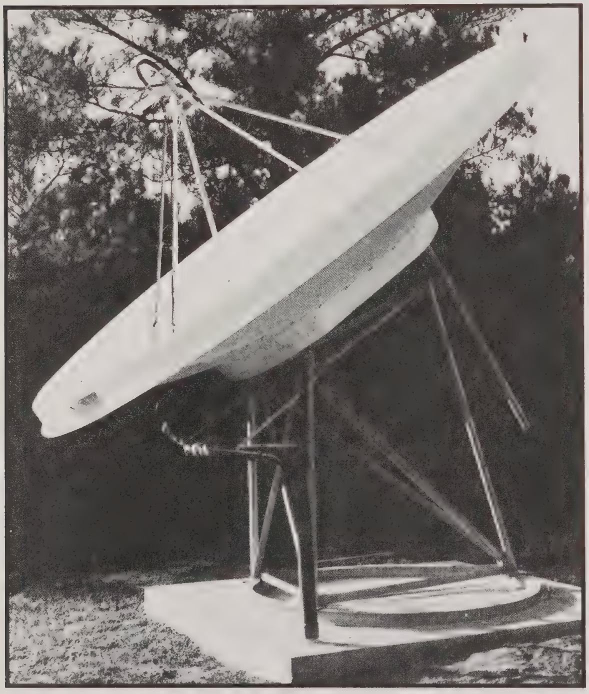


Figure 2-23. An Az-El Mount. *This 5 meter (16 foot) antenna is supported by a concrete pad and an az-el mount. (Courtesy of Comtech Antenna Corporation).*

Many actuators now have built-in counters based on potentiometers, Hall effect devices, Reed switches or optical couplers. A potentiometer, a variable resistor, receives a voltage from the control box. Depending upon the position of the jack arm it returns a corresponding lower voltage to monitor dish position. This method can be less accurate than a microprocessor control which uses digital pulse counting.

A Hall effect transistor or a Reed switch positioned in close proximity to a rotor bearing four magnets accomplishes the same task by generating a pulse for each quarter turn of this rotor. These pulse are relayed into the in-door controls via a small diameter wire and pulses are counted by the circuity. Once the pulse counter reaches that which has been programmed into the memory, the computer switches off the voltage to the actuator motor. This motion can be accurate to within 0.5 inches.

Optical counters work in a similar fashion. The difference in their operation is how they detect and count motion. Magnetic counters, like Hall effect transistors or Reed switches, generate a pulse when passed by a current carrying wire. And optical devices do the same when contact with a light beam, like a automotive timing light, is repeatedly strobed on and off as the dish moves. This is the most accurate method and is most important for higher frequency Ku-band broadcasts where precisely targeting satellites is critical.

Mechnical Construction

Linear Actuators

The most familiar actuator has a telescoping arm which moves into and out from a fixed external rod. The gear assemblies which drive the internal arm can be an acme thread or a ball screw.

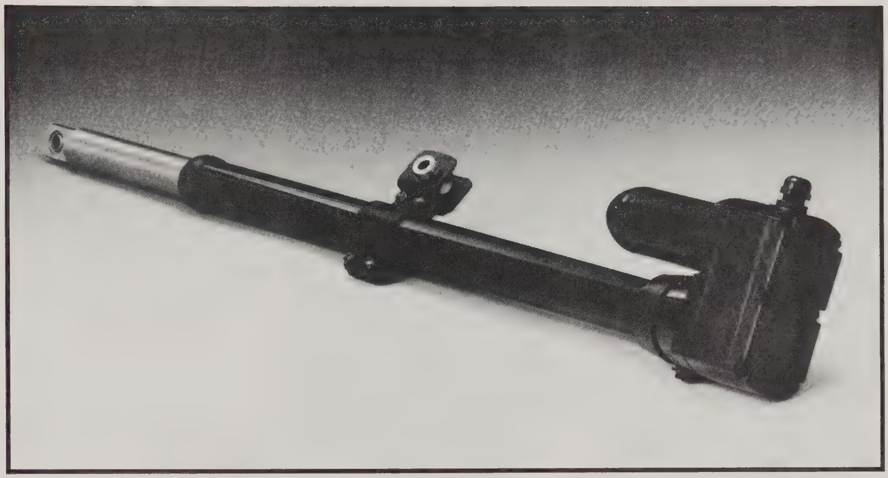


Figure 2-24. A Linear Actuator. *The acutator arm bolts onto the mount at one end and the dish at the other. A small, one tenth horsepower DC motor moves the inner arm to point the dish at any satellite along the arc. (Courtesy of Prosat, Inc.).*

The acme jack is constructed from a threaded shaft moving in a threaded collar. It is simple and lower in cost than the ball screw mechanism. The ball screw is similar but has ball bearings which replace the threaded collar that run in the threads. This mechanism has a much lower frictional loading than the acme so a motor of the same power will transmit more force to the dish. This increased force and the smoother ball bearing movement reduces the chance of the shaft seizing up during cold weather or after long periods of non-use.

As a general rule, an actuator arm should never have to push or pull an antenna through an angle of less than 30 degrees as measured from the surface of a dish. The larger this angle, which depends upon the design of the mount and the length of the actuator arm, the less the lateral force on the arm during dish movement. This lessens the chance that the internal arm could be damaged through bending. Note that this type of actuator is limited in its motion to about 100 degrees sweep across the arc.

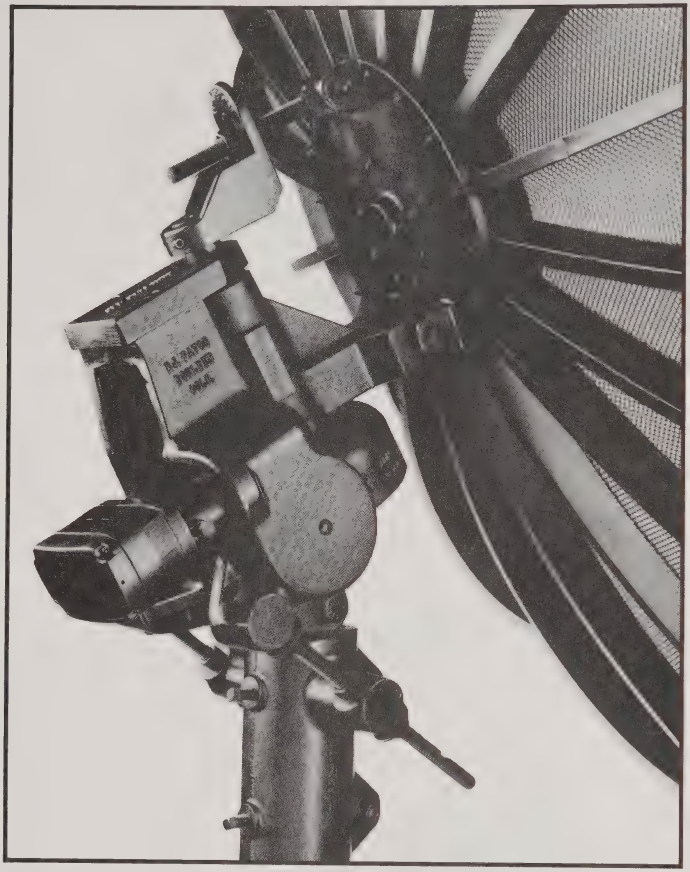


Figure 2-25. Horizon-to-Horizon Actuator. *The total mechanism for this type of actuator is contained at the dish support. It allows a tracking from one horizon to the other, not possible with a linear actuator. (Courtesy of GeoTrac, Inc.).*

Horizon-to-Horizon Actuators

Horizon-to-horizon actuators are attached to the base of an antenna. They must be solidly constructed to generate the torque necessary to rotate a dish and to allow minimal movement in winds or under other loads such as heavy snows or wind. These are designed to move an antenna from horizon to horizon with no difficulty.

Electrical Connections

Electrical connection between the actuator motor and in-door equipment is accomplished with a cable having four or five conductors. Two heavier gauge wires carry the 36 volt DC power required to drive the motor. Typically, for runs up to approximately 300 feet, 14 gauge wire is adequate; 12 gauge must be used for longer distances. Two lighter 20 gauge wires and often a ground are used to connect the counter to the control circuitry.

User and Receiver Interfaces

Control boxes which operate and direct the mechanical equipment at the dish are either one of two basic types. The simple manual controller features two buttons for east and west movements. The position of any satellite is identified by the count on a digital readout on the controller display panel. More sophisticated units have programmable memories to allow the operator to easily locate any satellite at the push of a button. Dish position is displayed by either a numerical counter or a digital readout showing satellite code or name. Often over 100 satellite positions can be programmed into these actuator control memories. Both types of

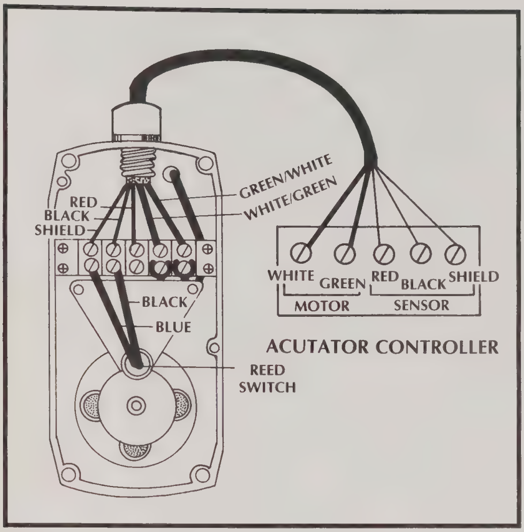


Figure 2-26. Electrical Interface Between Actuator and Controller. *Five wires connect a typical actuator arm to its control box. Two of these send a direct current to drive the motor either east or west; three relay counting pulses from a sensor to the controller. In this case a Reed switch sensor on a is diagrammed (see Chapter IV for more details).*

controllers should have east and west limits to prevent possible damage to motors, arms and antennas.

Some brands like the Houston Tracker IV Super Plus® or V can be interfaced with numerous brands of receivers by a multi-wire connection. The hand-held remote then controls dish position and channel selection by the choice of an appropriately coded button. Others like the Chaparral Sierra® block receiver have a built-in actuator and also one hand-held remote to control all functions. On this and other similar units with built-in actuators, satellite selection is displayed next to channel number on the receiver or on remote TV screen readouts that can be monitored from other sets inside the house.

D. FEEDHORNS

Feedhorns have the important function of collecting microwaves reflected from the antenna surface and of ignoring noise and other signals coming from off-axis directions. This must be done with minimal signal losses and without adding significant amounts of noise. A poorly designed feedhorn assembly can add as much as 20 K noise to a home satellite system. Feedhorns also select the required signal polarity and reject or discriminate against signals of the opposite polarity.

Illumination Patterns and f/D Ratios

The term feedhorn was derived from uplink antenna jargon. A feedhorn "sprayed" or fed microwaves onto the antenna surface below for reflection into space. Before the advent of powerful computers it was easier to design a downlink system by considering it as an uplink working in reverse. The terminology feedhorn has persisted as a descriptor of the collection device on a receiving antenna.

Therefore, feedhorns are said to "illuminate" a dish. The illumination pattern describes the field of view of a feedhorn. A perfectly illuminated system would detect radiation coming from nowhere but the antenna surface; it would reject radiation from any other source.

In practice, feedhorns illuminate the dish central regions most strongly and taper off in their ability to detect off-axis microwaves. A feedhorn which illuminated just the central por-

Figure 2-27. A selection of the Houston Tracker™ line of actuator controllers. *(Courtesy of Houston Satellite Systems, Inc.).*

tions of an antenna would introduce little environmental noise into the system but would miss some of the signal at the dish edges and hence result in lowered gain. A feedhorn which over- illuminated a dish would take advantage of all the available gain but would introduce too much ground noise. Remember that the ground on a typical cool summer day emits noise at a "hot" 290 K.

Feedhorn designers have determined that when the taper at the edge of a dish is set so that it receives between 14 and 16 db lower signal power than that at the dish center, collection efficiency and noise reduction are optimized.

The f/D ratio determines where a feedhorn must be located. Deeper dishes require feedhorns which can see out to wider angles. Feedhorns are optimized for specific values of f/D but can be used quite effectively for a range centered on this optimal value. For example, the Polorotor® I is designed for an f/D equal to 0.375 but works over a range spanning 0.30 to 0.44. The Chaparral Gold Ring® converts this feed to one designed for a 0.30 f/D. At a f/D of 0.25, the feedhorn is located in the same plane as the edge of a dish and adequately

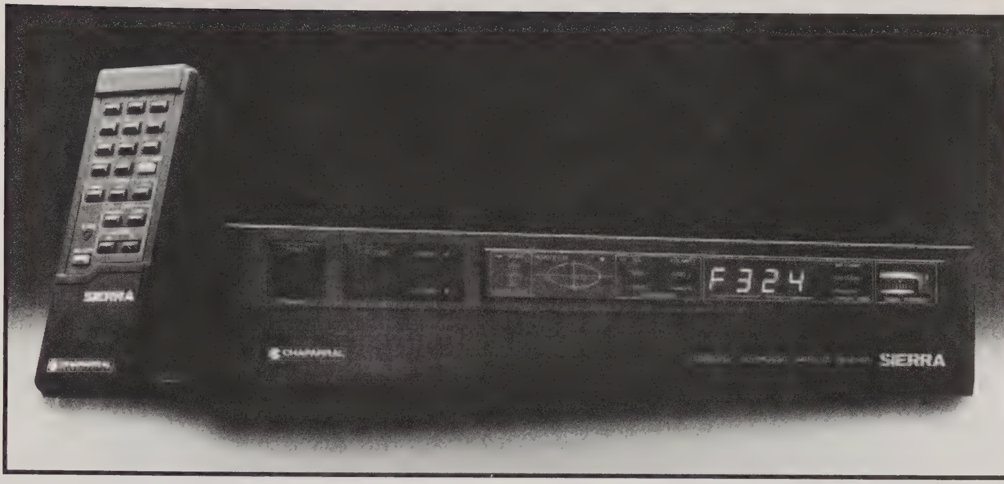


Figure 2-28. Chapparal Sierra™ Receiver. *This video receiver has a built-in actuator and a radio controlled remote control. (Courtesy of Chaparral Communications, Inc.).*

illuminating the edges becomes more and more difficult to achieve.

Feedhorns used with offset fed dishes must be specifically designed for this configuration. As in all other systems, the offset feed should see as much of the dish surface and as little of the surrounding terrain as possible.

More on Feedhorn Design

Feedhorns see electric and magnetic fields, i.e. microwaves, coming from a dish surface. In order to equalize reception of both these fields and, as a result, properly illuminate a dish, scalar rings are used. Feedhorns designed for higher frequency Ku-band broadcasts are proportionately smaller in relation to the wavelength.

Once the microwaves have been captured, they are channeled by a waveguide down the throat of the feedhorn. Waveguides are metal, hollow pipes of circular, rectangular or other crossectional shapes that transmit microwaves. They can be compared to fiber- optic cables that relay light. Microwave signals cannot be transmitted through waveguides unless they have a wavelength shorter than one half of the dimensions of this waveguide. The waveguide in a feedhorn must have precise dimensions to allow transmission of as much of the received radiation as possible.

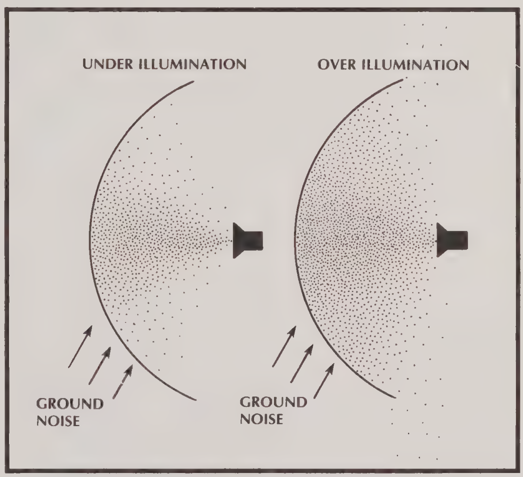


Figure 2-29. Feedhorn Illumination Patterns. *Both under- and over-illuminating a dish causes a lowering of signal to noise ratio. Under illumination means gain is lost; over illumination means too much noise is detected from spillover.*

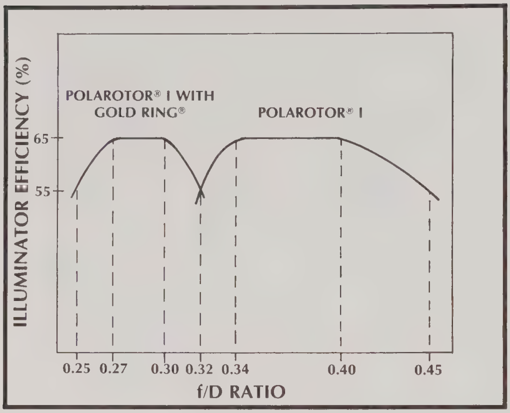


Figure 2-30. Illumination Efficiency. *Each type of feedhorn has peak performance at an optimal f/D but manages well over a rather broad range. This graph shows the performance of the Chaparrel Polarotor™ I. Attaching the Gold Ring™, a small metal insert, to the feedhorn changes its optimal f/D to that required by a deep dish range.*

A quantity called the VSWR or the voltage standing wave ratio measures how much of the incoming radiation is reflected backwards and lost (for a definition of VSWR see the Appendix). Feedhorn manufacturers must design their products to have a minimum VSWR. A perfect feedhorn would not reflect any microwaves back towards the dish and would thus have a VSWR of 1 to 1. VSWR ratios below 1.5 to 1 are acceptable but a high quality feed should have a ratio at least below 1.3 to 1. With this measurement, the lower the better.

Polarity Selection

Feedhorns must be capable of selecting the correct polarity format and of rejecting all others. American broadcast satellites relay signals with either vertical or horizontal polarizations. Circular polarities are used by satellites such as the Soviet Gorizont and Molniya and some Intelsat vehicles. Selection between vertical and horizontal formats are considered here.

Early feedhorns had a motor which simply rotated the whole body of the mechanism. This was cumbersome and subject to mechanical failure. Today a variety of more effective methods are used.

Mechanical Rotors

The mechanical servo motor feedhorn is the most popular type. A small feed probe is rotated over a 180 degree range to allow reception and fine tuning of either polarity. A similar type using a DC motor which as a full 360 degree range of movement is also popular but moves more slowly than the servo motor type. Most receivers available today have built-in controls for one or both of these types of polarity selection. These mechanical devices add insignificant amounts of noise to the satellite signal.

Ferrite Devices

Ferrite devices are solid-state mechanisms that have no moving parts. These feeds select polarity by sending current through a wire-wound piece of ferrite material. The magnetic field produced rotates the plane of polarization instantaneously. Ferrite devices cannot have mechanical failures (except for an unlikely short circuit) and are preferable in very cold climates installations where binding could occur. Mechanically driven probes could have failures in such environments. Unlike their mechanical counterparts, ferrite polarity selection devices have some insertion loss or noise, typically about 15 to 30 degrees Kelvin or 0.2 to 0.4 decibels.

Pin Diodes

Pin diode switching is the least popular since only two directions of polarity can be selected based on the orientation of two pin diodes. The polarity setting cannot be fine tuned. Pin diodes are also relatively high in loss and noise contribution.

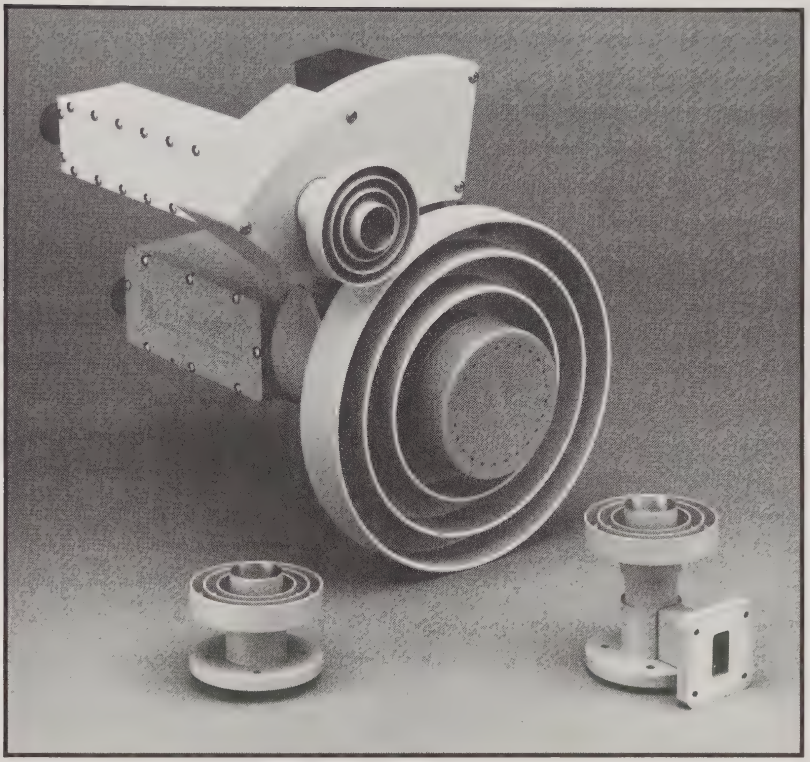


Figure 2-31. C- and Ku-Band Feedhorns. *This illustration shows the relative size of the C- and Ku-band feedhorns. These Chaparral™ Ku-band feeds are designed to operate with an f/D ratio between 0.33 and 0.45 and provide a VSWR of 1.3 to 1 over the entire frequency range, 11.7 to 12.7 GHz. The dual purpose feedhorn shown here is capable of simultaneously detecting both types of satellites broadcasts. (Courtesy of Chaparral Communications, Inc.).*

Dual Feedhorns

Dual polarity feedhorns or "orthomode couplers" can choose both vertical and horizontal polarities at once. Such devices are common in commercial installations and are becoming more common in home satellite TV systems because they allow simultaneous viewing of all 24 channels on each satellite.

Operation of these devices is based on the property of waveguides to reject the passage of microwaves having wavelengths longer than one half its dimension. For example, if signals with a 1 centimeter wavelength reach a waveguide having a cross-section of 2 by 0.3 centimeters, only those waves polarized in the wider dimension of 2 centimeters will pass through.

A dual feedhorn uses two waveguides of the required dimensions at right angles to each other. One arm transmits horizontal polarity; the other vertical polarity. Two low noise amplifiers are used to amplify each of these signals.

Customer Interfaces

Polarity selection is controlled from the video receiver in three ways. First, the receiver triggers an automatic polarity change when channels are switched from an even to an odd numbered station and vice-versa. Second, once the channel has been selected, a skew adjustment allows for fine tuning of probe position. Third, since two different polarity formats are used by American broadcast satellites (either all even channels are vertically or horizontally polarized), receivers have an even/odd polarity selection control which changes probe position at the press of a button.

Programmable units accomplish channel selection and polarity format adjustments automatically. Some more sophisticated units also fine tune and optimize polarity by employing feedback circuits which maximize signal strength when a given channel is selected.

Most receivers are designed to accept the necessary wires, typically three fine gauge ones, to control polarity selection and fine tuning.

E. LOW NOISE AMPLIFIERS

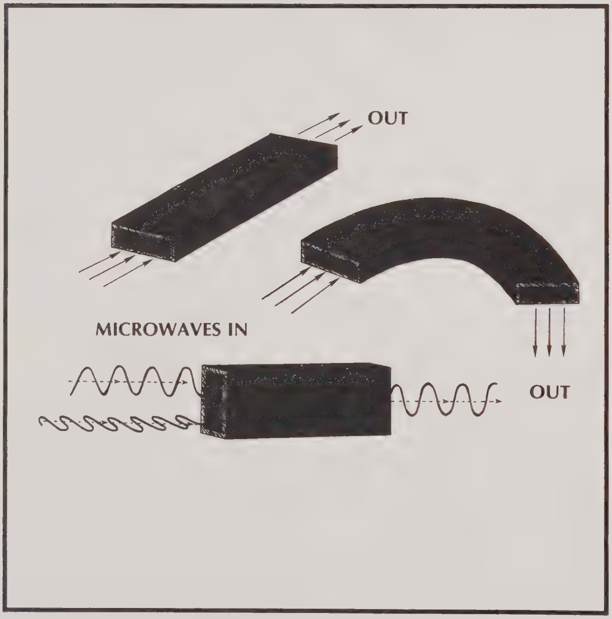


Figure 2-32. Waveguides. *Microwave signals can be relayed along waveguides. Waveguides of the proper dimensions can also separate vertically from horizontally polarized waves.*

Low noise amplifiers (LNAs) have the important function of detecting microwaves relayed from the feedhorn, converting them to electrical currents and amplifying this extremely weak signal by 40 to 50 decibels (10,000 to 100,000 times). The antenna and LNA working in unison are the most important parts in determining how well an earth station functions. The LNA is the first "active" or electronic component in the chain of processing a satellite signal.

The power reaching the input of an LNA is still incredibly low at less than one hundred thousandth of a billionth of a watt. The LNA must contribute very little noise power or this signal will be drowned out in the roar of noise from the internal workings of the amplifier. This feat is made possible by recent advances in transistor technology. Without this progress, satellite TV would not exist as we know it today.

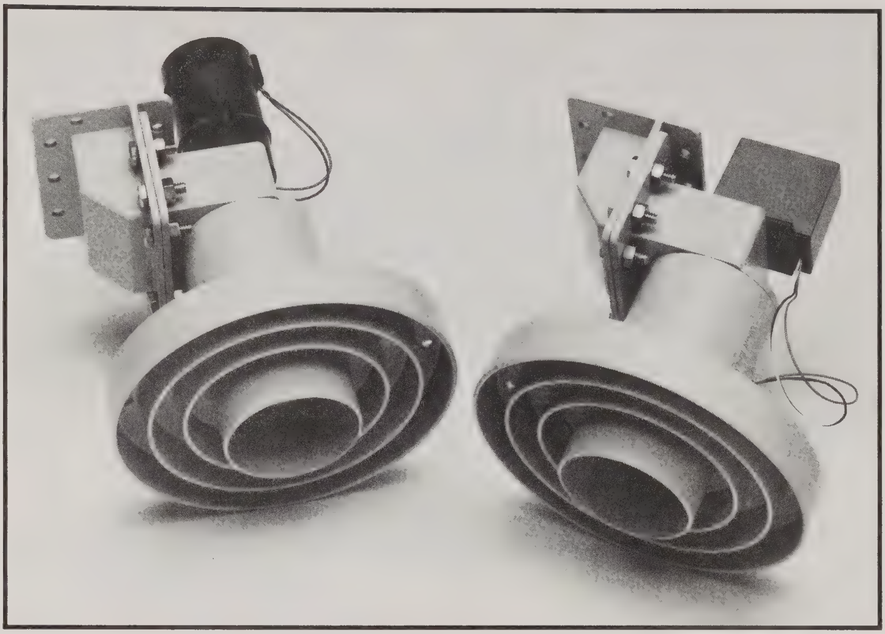


Figure 2-33. The Chaparral Polarotor™ I and II. *The probes inside the Polarotor™ I and Polarotor™ II are driven by a servo motor and a DC motor, respectively. Both of these polarity selection devices rotate to their final position in less than half a second. Both can also be interfaced with circuitry in most receivers or be controlled by a separate box. Note that the DC motor moves more slowly than the servo motor polarizer. (Courtesy of Chaparral Communications, Inc.).*

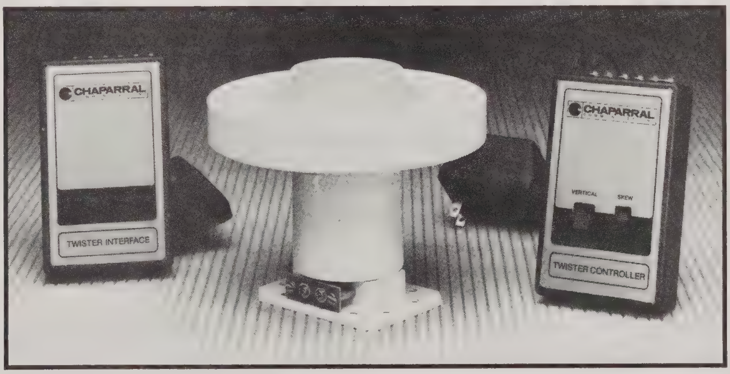


Figure 2-34. The Chaparral Twister™ I. *The Twister™ I is an example of a ferrite polarity selection device. It includes total skew and adjustment capability and will interface with any Polarotor™ I controller, whether in a receiver or a stand-alone unit. (Courtesy of Chaparral Communications, Inc.).*

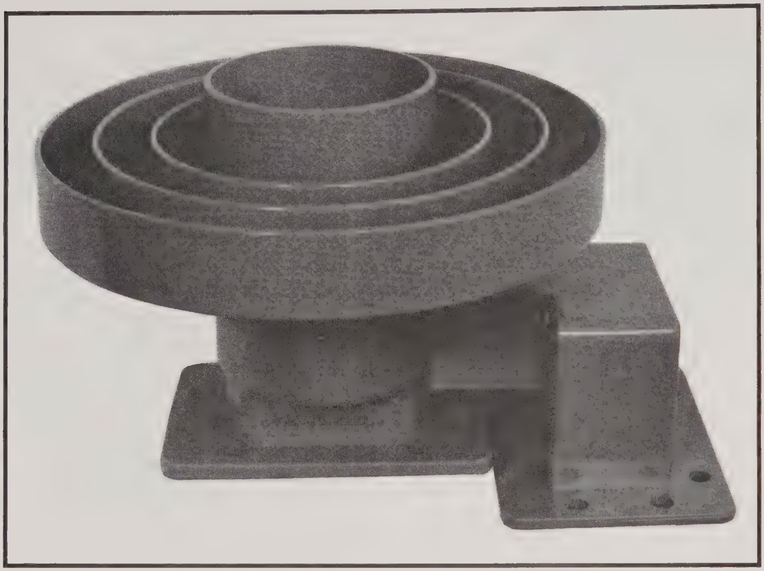


Figure 2-35. Dual Feedhorn. *A dual feedhorn used with two LNAs is capable of simultaneously receiving both vertically and horizontally polarized signals. (Courtesy of Chaparral Communications, Inc.).*

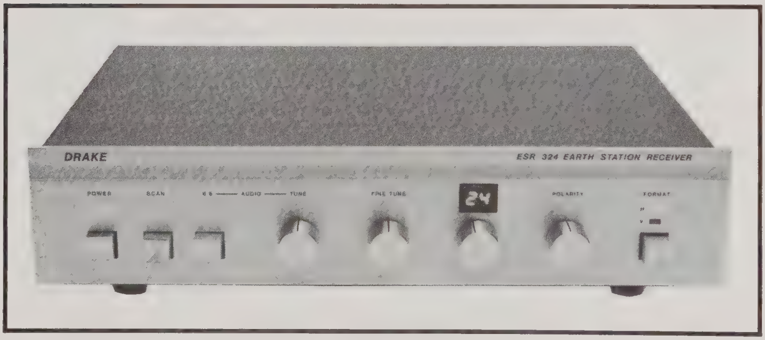


Figure 2-36. Channel Selection and Skew Adjustment. *The front panel of this Drake ESR 324 receiver has knobs for channel selection and skew adjustment and a push button for polarity format selection. All of these change position of the feed probe. (Courtesy of the R.L. Drake Company).*

The original LNAs used in radio astronomy were ordinary parametric transistor circuits which were immersed in baths of extremely cold liquid nitrogen or helium. This technique kept noise levels low by slowing down molecular motion, the source of background noise. The development of the gallium arsenide field effect transistor, known as gaasfets, made the modern LNA possible. These special transistors trick the amplifier into behaving as if it were operating near absolute zero where all molecular motion ceases.

More on Noise Temperature and Figure

An understanding of noise is critical in satellite broadcasting because the minute signals are just a step stronger than the ever-present noise. Noise is caused by molecular motions which generate electrical currents and, as a result, electromagnetic waves some of which are in the same microwave frequency band as satellite transmissions. The scale employed to measure noise is based on the fact that at zero degrees Kelvin, known as absolute zero (minus 273.18 °C or minus 459.72 °F), there is no noise. Typical LNAs have noise temperatures ranging from 60 to 120 K.

Interference is also considered a form of noise even though it usually originates from some other man-made source or communication device. Higher quality LNAs having lower noise temperatures will detect less random noise but are more capable of seeing other organized signals from either satellites or man-made sources.

Noise power is directly related to the signal bandwidth as well as the temperature inside electronics and in the environment. As bandwidth increases, more noise can be detected and added to any signal. So decreasing the bandwidth of signals allowed into an amplifier will decrease the amount of noise and interference which can be detected.

The noise characteristics of an LNA or any other electronic device are sometimes described in terms of the noise factor. This quantity is directly related to the amount of noise added by the internal workings of such devices. The noise figure is simply the noise factor expressed in decibels. More details showing how noise temperature and noise figure are related are outlined in the appendix. Some typical values of these quantities are shown in Table 2-5 below:

TABLE 2-5. EQUIVALENT NOISE FIGURES AND TEMPERATURES

Noise Temperature (K)	Noise Figure (dB)
60	0.819
65	0.881
70	0.942
75	1.002
80	1.061
85	1.120
90	1.177
95	1.234
100	1.291
110	1.401
120	1.508

How does substituting an LNA having a lower noise temperature affect system performance? The method used to calculate this change can be clearly seen from an example. If a 120 K LNA were replaced with a 60 K unit in a system whose dish added 40 K of noise, the signal to noise ratio would improve by:

$$(120 + 40)/(60 + 40) = 1.6$$

This factor of 1.6 or 60% performance improvement is equivalent to a 2 dB change (equal to 10 log 1.6). It is interesting to realize that an equivalent 2 dB improvement in gain can also be achieved by upgrading from an 8 to a 10 foot dish (see Table 2- 2).

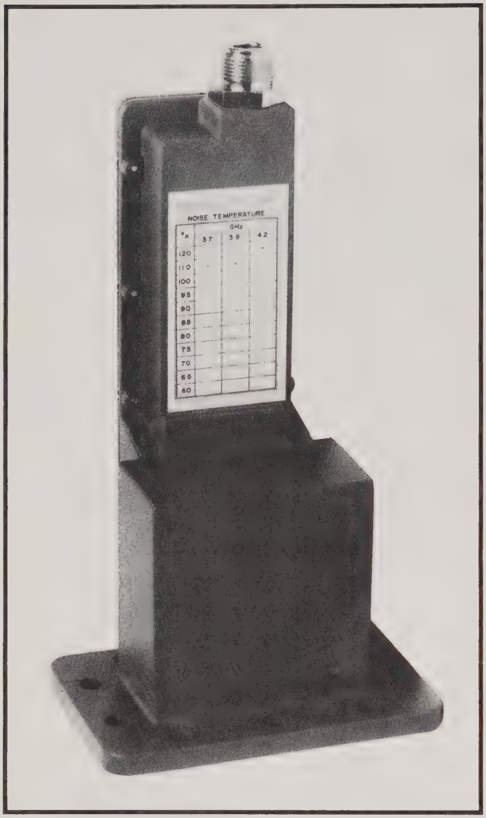


Figure 2-37. Low Noise Amplifier. *This 85 K LNA is the first active electronic component of a satellite TV receiving station. (Courtesy of Avantek Corporation).*

LNA Design and Operation

All LNA designs are similar in shape because the waveguide section must have the appropriate dimensions to channel C-band microwaves. The input flange and waveguide, known technically as a WR-229 choke with waveguide, has dimensions of 2.29 by 1.145 inches. Occasionally, fine tuning controls are built-into the waveguide portion of an LNA to allow slight changes in its internal dimensions. These permit the precisely manufactured LNA to be even further tweaked to maximum performance on sophisticated equipment. Such tuning minimizes the amount of signal lost in entering the LNA.

Every LNA has an internal probe which is the real microwave antenna. This small metal antenna receives microwaves and converts them into electrical currents. A DC shorted probe prevents high voltages which are caused by nearby lightning strikes from frying the internal components. (Note that direct strikes will destroy any LNA.). The probe is set at precisely the correct position to maximize signal reception and should never be tampered with even if it appears to be slightly bent.

The electronic components of an LNA are enclosed in a hermetically sealed box. Water vapor has a very destructive effect on the operation of electronic components and is carefully avoided by such design.

Each LNA consists of several gaasfet transistor stages (usually two or three) in a cascaded arrangement followed by several conventional amplification stages. A voltage regulator is also included in the circuit. LNAs usually draw between 80 to 150 milliamps of current and operate at 15 to 24 volts DC.

Judging LNA Performance

The major factor in judging LNA performance and quality is its noise temperature. This assumes that the gain is sufficient and that important design issues have been adequately addressed.

Noise Temperature

The LNA is the "front end" of a satellite TV receiving system. The noise it adds to the incoming signal sets the noise floor and plays a large part in determining picture quality. LNAs

are now available at reasonable prices having noise temperatures ranging from 120 K to as low as 55 K. This is extraordinary considering that as recently as 1981 an 85 K LNA retailed for over $5000 while today it can be purchased for less than $100.

LNA noise temperatures vary across the design frequency band. Most manufacturers will print the noise temperatures measured at 3.7, 4.0 and 4.2 GHz on an attached plate. The overall rating should reflect the highest noise temperature in this range.

LNA performance is determined to some extent by its ambient operating temperature. Thus, for example, if a LNA with a black cover was functioning at high noon in a desert and had its body temperature raised to 140 °F, it would certainly generate more noise. The sensitivity of LNA noise temperature to ambient temperature can vary from 0.8 to 0.5 K for every 10°C (18°F) temperature rise above 25°C (77°F). To illustrate, a 90 K LNA could function as a 92 degree unit if the operating temperature were raised by 20°C (36°F). Performance would improve by the same measure if the operating temperature were lower. Most manufacturers shield their products from temperature extremes by using a rubber or enamel paint. Spot cooling devices for lowering noise temperatures are even available in systems where top performance is crucial. One variety called cooling wafers can be stuck onto the outside of the LNA housing. Then when current is turned on the temperature of the LNA is slightly lowered.

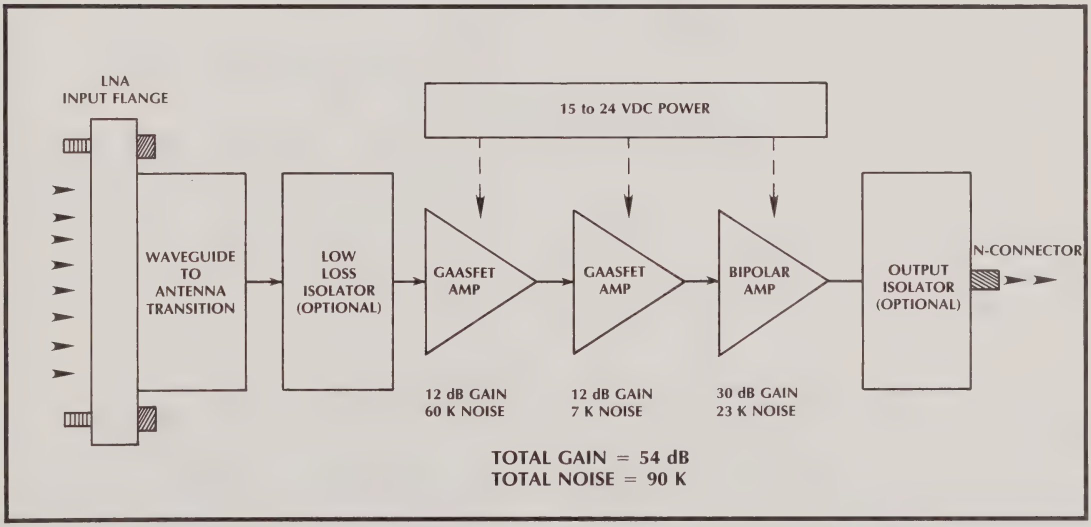


Figure 2-38. LNA Schematic. *Each stage of an LNA contributes to noise and gain. The gaasfet stages are responsible for the low noise temperatures. In this example, each gaasfet stage provides 12dB of gain; the two or more bipolar stages provide 30 dB additional gain.*

Gain

LNA gains range from as low as 30 dB to over 50 dB. The bottom line with LNA gain is simple. Either it is enough or it is not enough. Past a certain point adding extra gain will do nothing for improving system performance. Tests have shown that this point occurs somewhere between 35 and 40 dB, but 40 dB should be considered a minimum gain especially when using an undersized or a smaller dishes and/or 4 gigaHertz cable runs exceeding approximately 6 feet between the LNA and downconverter.

Gain also varies with ambient temperature and frequency. As temperature increases gain decreases, typically about 0.6 dB for each 10°C temperature rise. This variation is of little significance except for operation in extremely hostile environments such as outer space. Small variations in gain also occur across the C-band frequency range. A perfectly "linear" LNA would amplify every frequency equally but generally the variations are small enough to be negligible. Large deviations from linearity which could cause an LNA to become unstable and oscillate are more possible at extremely low ambient temperatures below -40 °F.

A perfect LNA would amplify signals only in the designed frequency band and reject those outside. In practice, gain drops off rapidly but measureably at frequencies outside the band. Out-of-band rejection is important especially in cases when other local communicators using nearby frequencies could be inadvertently detected. The two most likely culprits would be microwave amateur or Air Force radar at 3.5 and 4.4 GHz, respectively. Out-of-band rejection is also more of a concern for block downconversion than for 70 MHz systems (see next section) where frequencies ranging from 450 to 1450 MHz nearer to the C-band are transmitted. Some LNAs have produced significant gain and noise in this 450 to 1450 MHz range. Most well-made LNAs have bandpass filters, devices which reject freqencies under 3.7 GHz and over 4.2 GHz, to minimize the likelyhood of such problems occuring. Note that LNAs, like feedhorns, also have a rated VSWR. This "voltage standing wave ratio" is found by dividing the power of the input signal to that of the input signal actually entering the LNA. When no signal is reflected back towards the feedhorn in a perfect device, the ratio is 1 to 1. VSWRs are below 1.3 to 1 in higher quality LNAs.

LNAs, LNBs and LNCs

Some low noise amplifiers not only amplify the satellite signal but perform some of the functions expected of a downconverter. Downconverters do just what the name implies. They lower all or part of the frequency range from 3.7 to 4.2 GHz to either the final targeted 70

TABLE 2-6. COMPARING LNAs, LNBs AND LNCs

	LNA	LNB	LNC
Amplification	x	x	x
Downconversion		x	x
Channel Selection			x

MHz or to some intermediate range. In a conventional system, a short cable run or connector is used between the LNA and downconverter, which is mounted adjacent to the LNA or just below the dish for best results.

An LNC combines the functions of a downconverter and LNA in one unit. This device lowers the frequency of each satellite channel to 70 MHz in turn as requested by the in-doors receiver.

An LNB combines the functions of a block downconverter and LNA in one unit. It lowers the frequency of the whole 500 MHz band in one step to an intermediate range. More will be said about such arrangements in the following discussion on downconverters.

Electrical Connections

The electrical connections to an LNA, LNB or LNC are simple. LNAs have an output female N-connector which is joined either directly or via a short RG-214 coaxial cable run to a downconverter. LNBs and LNCs use an F-connector and can be directly cabled into the video receiver. Earlier low noise amplifiers required the use of a second power cable. Today, power is almost always relayed via the signal-carrying coax.

F. COAXIAL CABLE

The LNA and downconverter as well as the downconverter and the receiver are connected to each other by a special configuration of conductors called coaxial cable, coax. Single wires of copper or aluminum are adequate for conducting electricity at lower frequencies encountered in most familiar electrical devices. However, when higher frequency microwaves are relayed, single strands of metal behave like antennas and can radiate away most of the power. With exceptionally high frequency signals, such as those used in satellite broadcasting, specially designed cable must be used to prevent almost complete loss or attenuation of the transmitted signal.

Coax is composed of two concentric conductors separated by an insulating material called a dielectric. This whole assembly is sheathed in a non-conducting jacket for protection against the elements. The signal travels on the surface of the central wire. The external cylindrical conductor is grounded and greatly reduces radiative losses at high signal frequencies.

Types of Coax

A wide range of coaxial cables are available. Coaxial cable is usually referred to as either hardline, coax, or foam or air dielectric coax depending upon the construction of the sheathing material, the dielectric. Coax has one or two pliable metal grounded layers wrapped around a plastic dielectric. Dielectrics used for home satellite TV coax are either polypropylene, a hard, translucent substance, or polyethylene foam, a soft, white material. The outer conductor, which is often a braided copper or aluminum sheath, is occasionally doubled up or replaced with a solid casing to further lower losses and lessen the chance of ingress interference. The degree of cable braiding is rated by the percentage of the inner area shielded. 98% shielding is a typical value. Cables shielded 100% are recommended for installations where ingress interference caused by local communicators using frequency bands near the satellite C-band may be expected.

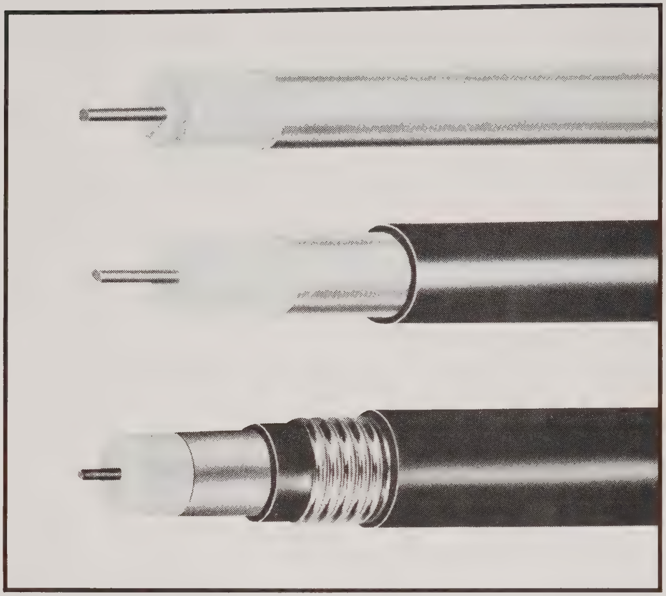


Figure 2-39. Coaxial Cable. *These three examples of coaxial cable for high frequency signal conduction are protected to increasing degrees. The middle one has a polyethylene jacket while the lower one has two metal jackets one being a corrugated chrome plated steel armor to prevent the cable from being bent too sharply. (Courtesy of M/A COM, Comm/Scope Marketing, Inc).*

Foam or air dielectric coax uses either foam or compressed air as the dielectric material and is generally lower loss and more expensive than ordinary coax. Hardline is similar in construction to either of the previous two types except it has even lower losses because it has a more rigid, metal sheath and a minimal amount of high quality dielectric. Hardline is usually used in the main trunk lines of cable TV or other similar communication network such as SMATV systems.

Cable types often encountered in satellite TV installations are RG-6, RG-59 and RG-214. The latter is rated for microwave frequencies and is used, when necessary, between the LNA and downconverter. RG-6 and RG-59 transmit the lower frequency IF signals from downconverter or LNB to a satellite receiver. Note that the nomenclature for coaxial cable is of military origin so these designations have no particular significance in the home satellite TV market.

Judging Cable Performance and Use

Coaxial cable is judged according to performance criteria including characteristic impedance, loss of signal power per unit distance and material composition. These factors determine which types are suitable for which uses.

Characteristic Impedance

Every conductor has a certain resistance to current flow which causes some signal loss. Also, voltages on the inner and outer conductors interact with each other (known technically as capacitance and inductance). These two factors determine a value called the characteristic impedance. The most common values for coax used in TV distribution systems are 50 and 75 ohms.

Knowing the characteristic impedance is crucial in designing electronic systems. Every electronic device also has a characteristic impedance. If the impedance of the cable does not match the device it feeds, there will be substantial reflective power loss. This mismatch would be similar to sending water from a larger diameter into a smaller diameter pipe and experiencing resistance to flow. Similarly, if the output impedance of an amplifier is not matched to the coaxial line impedance, reflections and losses will occur.

This idea is similar to the concept underlying VSWR, the measurement of signal reflection, used for both feedhorns and LNAs. If the impedances are matched between the antenna, within the feedhorn components, between the feedhorn and LNA, and internally in the LNA, losses will be at acceptably low levels. Any weak point in this chain will seriously degrade system performance.

Many LNAs on the market today use a component called a ferrite isolator. This device, an integral part of older models, allows signals to enter an LNA but absorbs most reflected power and therefore acts as an impedance matching device. It has been one of the more expensive components of an LNA. When the isolator is removed, LNA noise temperature could be as much as 20 K lower than an equivalent unit. Although some have argued that this advantage is lost because the impedance mismatch from eliminating the isolator results in additional signal attenuation and noise, recent measurements have shown that this is not the case.

Signal Losses

Coax is rated according to decibels of loss per distance. These per distance losses are frequency dependant. Some cables like RG-6 which have perfectly acceptable losses at 1 GHz are unuseable at 4 GHz. RG-214 has an attenuation of 21.5 dB per 100 feet (0.215 dB per foot) at 4 GHz. So relaying a signal of 4 GHz on RG-214 coax over a 14 foot distance results in a loss of 3 dB or a halving of signal power. When using 950 to 1450 MHz block downconversion systems RG-6 loses 8.7 dB per 100 feet at the higher frequency end, so a run of 150 feet will result in 13.1 dB attenuation. It is clear that cable runs should always be as short as possible. Such considerations dictate that for cable runs between the downconverter and satellite receiver in excess of 150 feet, RG-6 cable should be used instead of the higher loss RG-59.

Values for signal loss per distance at frequencies of 100 MHz, 1450 MHz and 4 GHz in cables often use in satellite TV installations are listed in Table 2-7.

In general, the higher the frequency of the signal the greater are the losses. And errors made when installing cables and connectors can cause more deterioration in performance when higher frequency signals are used. To illustrate, if a coaxial cable is not properly connected to the rear of a LNA, there will be over 70% more losses at 12 GHz than at 4 GHz. Modern video receivers which downconvert at the dish have two advantages over earlier models which relayed the higher frequency 4 GHz signals in-doors. Less money is spent on coax and problems caused by potential installation errors are minimized. The losses in each cable type can also dependent on contruction details such as the diameter of the central conductor.

TABLE 2-7. CHARACTERISTICS OF COMMONLY USED COAX

Cable Type	Signal Loss (dB/100 feet) 100MHz	1450MHz	4 GHz	Impedance (Ohms)
RG-59	3.40	11	N/A	75
RG-6A	2.70	8.7	N/A	75
RG-11	2.30	7.0	N/A	75
RG-8A	1.90		23.0	50
RG-213	1.90		21.5	50
RG-214	2.30		21.5	50
9913	N/A		11.0	50
9914	N/A		13.0	50

For example, Alpha cables 9059 and 9803, both RG-59 designations, have different diameter central wires. As a result, they have different attenuations at 900 MHz of 10.7 and 10.2 dB per 100 feet, respectively. Table 2-8 shows some examples for cable manufactured by Belden. The attenuation values at 400 and 900 MHz are applicable to block downconversion systems.

Losses in excess of rated values can also occur in coaxial cables. If cables are bent too severely, the impedence at the sharp bend will be changed and reflective losses could occur. To illustrate, RG-8A has a foam dielectric and keeping the central conductor aligned directly down the middle of the grounded shield is difficult if a wide turning radius is not used, particularly when the cable gets hot. Misalignment causes the impedance to change at this sharp turn. A suggested minimum cable turn radius is 5 cable diameters.

Losses can also be substantial where connectors join cables. If these connectors are not joined properly, impedance mismatches and resulting losses can occur. It is important to examine the inside of each connector before mating. This will ensure that the center pin or conductor is not broken off and that it is ex-

TABLE 2-8. COAXIAL CABLE LOSSES AND CONSTRUCTION

Cable Type	Model	Shield Type	Attenuation (dB/100 ft) 400 MHz	900MHz
RG-6	8228	Foil & Wire	4.5	6.9
RG-6	9248	Foil & Copper Braid	4.5	6.9
RG-11	9230	Foil & Wire	3.2	5.2
RG-11	9292	Foil & Copper Braid	3.2	5.2
RG-59	8241	95% Copper	7.1	10.9
RG-59	9275	Foil & Wire	5.4	8.4

tended far enough out from the connector to make electrical contact but that it is not too far to short out to a chassis causing damage when attached.

To summarize, coax should be carefully selected so impedances are properly matched and so the frequency carrying ability is adequate. The distances between the LNA and downconverter and receiver should be made as short as possible. Also, connectors selected must be rated to carry the frequencies chosen and all connections must be secure and waterproof.

Water and Aging

Coaxial cable can be destroyed by intrusion of water, especially salt water. As well, any water leaks at connectors or along the cable body can short out a signal and, perhaps, damage a receiver or downconverter by shorting the LNA power to ground.

Underground moisture which comes into contact with any buried cable metals can cause very rapid corrosion. It is reported that tubular aluminum outer conductors have been almost completely destroyed in 90 days. Even small pinholes in jackets can allow this chain of events to occur. Poor installation or cable handling techniques or even rodents can cause such damage.

Most direct burial cables on the market today are sufficient for the job. But time will tell whether or not conduit should be used to protect these cables. Commercial installations use, when necessary, more expensive cables having a flooding compound under the jacket to protect against water. For maximum reliability against rodents, a steel tape armor with overjacketing or rigid conduit such as grey electrical PVC is suggested.

G. DOWNCONVERTERS

Once the downlinked 500 MHz band of frequencies has been amplified by the LNA, it is sent to a downconverter via either coaxial cable or a male-to-male direct couple N-connector. The downconverter translates either part or all of the 3.7 to 4.2 GHz signal to a lower frequency range. This contains the identical information. The purpose of this step is to allow use of inexpensive, lower loss cable, such as RG-6 or RG-59, to send this signal in-doors.

Background and Evolution

The first satellite receivers which appeared on the market had downconverters built-in along with all the other components necessary to extract the original audio and video information. This required use of expensive, low-loss air or foam dieletric cables. These cables could not have sharp bends and required the use of

difficult-to-install N-connectors. Antennas had to be mounted as closely as possible to the in-doors receiver or expensive 4 GHZ line amplifiers often costing thousands of dollars were required. All in all, installations had severe limitations and higher costs.

The basic improvement was to break the satellite receiver down into two components: a downconverter; and the remaining electronics. Thus, a short length of less expensive RG-214 cable could be used between the LNA and downconverter and even lower cost RG-6 or RG-59 relayed the downconverted signal to its final destination, the receiver. Cable runs even in excess of hundreds of feet could then be tolerated.

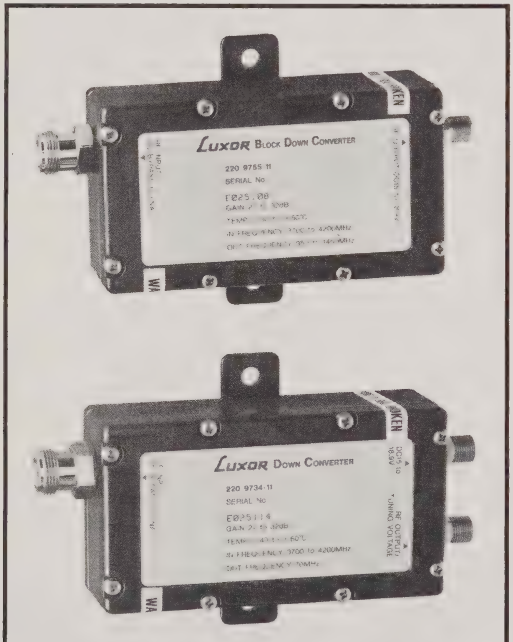


Figure 2-40. Single and Block Downconverters. *Every receiver comes with a matched downconverter which is installed at the antenna. (Courtesy of Luxor North America Corporation).*

Next, the downconverter was added to the LNA to create an LNC. Amplification and downconversion was accomplished in the same component mounted at the dish focus. This eliminated a separate box, cable and two connectors.

Block downconversion systems are a rather recent introduction. Such devices lower the complete 500 MHz band at once to some intermediate frequency. It can be accomplished using a separate LNA and block downconverter or by merging these two components into one box thus creating an LNB.

LNCs were never well accepted by the industry for two reasons. Unlike the more conventional LNA/downconverter, if an LNC had a problem, a lower cost LNA could not simply be swapped for a working unit. Also, systems using LNCs, unlike both LNA and LNB designs, cannot be used for multiple receiver, independent channel selection since only one LNC can be used per dish. On the other hand, LNB systems are ideal for multiple receiver designs.

Methods of Downconversion

Three distinct types of downconversion schemes are in use today: single downconversion; dual donwconversion; and block downconversion. In order to understand how these operate it is necessary to examine the way channels are selected.

Each of the twenty four channels downlinked occupies a 36 MHz bandwidth. The selection of any one of these is accomplished when its 36 MHz band is translated down to one centering on 70 MHz or another final IF. Thus, for example, if channel 10 having a center frequency of 3900 MHz and a bandwidth of 36 MHz is desired, the downconverter/receiver electronics lowers this block of frequencies to one centered on 70 MHz. If channel 22 centered on 4140 MHz is selected, the 36 MHz range around this frequency is also lowered to one centered on 70 MHz. And all other channels follow suit.

Downconversion is accomplished by a process called heterodyning or mixing. To illustrate, if a 1000 MHz signal is mixed with one of 900 MHz, the resulting sum and difference frequencies of 1900 and 100 MHz are created. So when a selective filter removes the higher frequencies, the effect has been to lower the 1000 MHz signal to one still containing all the original information but centered on 100 MHz.

A satellite receiver sends a voltage to a voltage tuned oscillator (VTO) which produces a desired mixing frequency. In single or dual conversion units the VTO is in the downconverter. In block downconversion systems the variable oscillator is in-doors in the receiver and the downconverter oscillator is set on a fixed frequency.

The standard 70 MHz IF is an arbitrary choice. Another frequency could be used. For example, DX receivers use both a 130 MHz and 134 MHz IF. Hitachi and Maspro components are designed for 612 MHz and 400 MHz IF, respectively. However, this generally accepted standard arose because when satellite receivers were being developed a circuit called a phase lock loop (PLL) detector, required for video receivers, was available operating to a maximum frequency of 35 MHz. These electronics had been used in the telephone microwave industry. The 70 MHz satellite IF was divided by two and conventional, lower cost components were used. Today, PLL detectors operate up to as high as 612 MHz. Many receiver manufacturers have retained this relatively low 70 MHz IF because cable losses are lower than if a higher frequency PLL detector were used.

Single Downconversion

Single downconverters lower the chosen satellite channel to the 70 MHz IF in one step. A channel selection knob or button chooses a voltage which is sent to the VTO. A mixing frequency 70 MHz lower or higher than the center channel frequency is produced and, after mixing the resultant difference frequency is 70 MHz, as desired. To illustrate, if channel 10 having a center frequency of 3900 MHz is selected, the mixing frequency is set at 3830 MHz; if channel 17 having a center frequency of 4040 MHz is chosen the VTO generates a mixing frequency of 3970 MHz.

Single downconversion has a potential problem because an image frequency 70 MHz above or below the desired channel center frequency is also be produced and can leak back into the system. A circuit called an image reject mixer in all video receivers partially eliminates this problem. A ferrite isolator installed on the downconverter input provides additional protection by blocking these unwanted signals from entering the system.

Dual Downconversion

Dual downconverters attain the final IF in two stages. An intermediate frequency, often but not always 810 MHz, is used as the target of channel selection. Then a fixed oscillator called a local oscillator (LO) set at 70 MHz below the intermediate frequency is mixed to produce the final 70 MHz. To illustrate, if channel 10 having a 3900 MHz center frequency is chosen, the VTO mixes it with a frequency of 3900 less 810 MHz or 3080 MHz. Then the intermediate 810 MHz is mixed with 740 MHz from the LO to lower the signal to one centered on 70 MHz.

Block Downconversion

Block downconverters use an LO to downconvert the whole 500 MHz satellite band to an intermediate range. Two frequency ranges are being favored as conventions: 950 to 1450 MHz; and 440 to 940 MHz both having 500

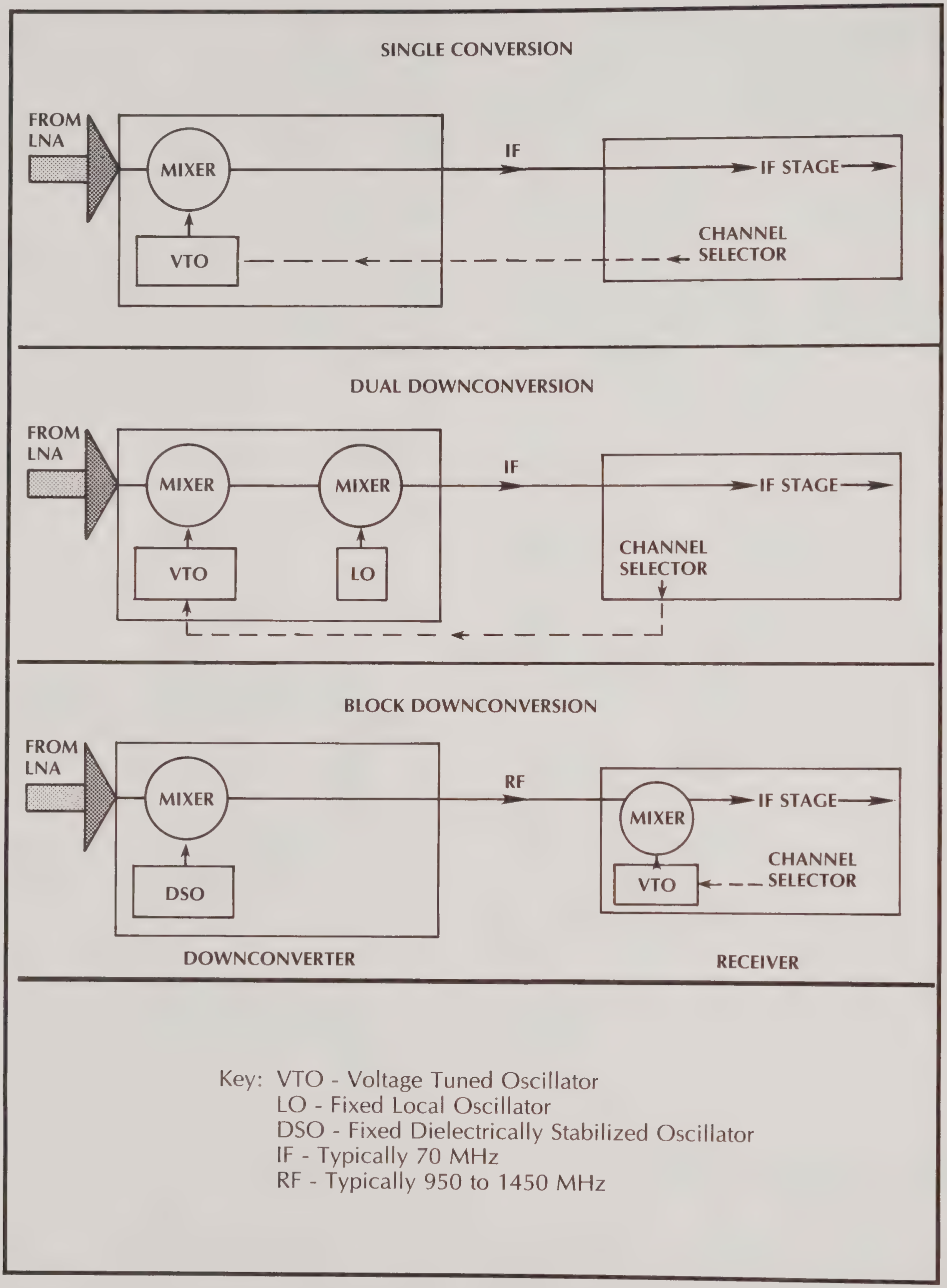


Figure 2-41. Downconversion Methods. *Single, dual and block downconversions systems all accomplish the same end result, channel selection and downconversion, using different methods.*

MHz bandwidths and containing all the original information as the 3.7 to 4.2 GHz band. This is sent in-doors to the video receiver. Then a VTO mixes this band with the channel selection frequency in the second downconverter to produce the final IF, typically 70 MHz.

Block downconversion systems have one outstanding advantage. Two or more receivers can independently select channels because each one using its internal mixer and VTO can choose from the lower frequency intermediate block containing all the information relayed from the dish. Block downconversion satellite receivers also are less subject to drifting off the target channel because channel selection occurs in-doors where electronic components are protected from large temperature and humidity swings.

Both of the intermediate frequency ranges have advantages and disadvantages. The lower one, 440 to 940 MHz, allows use of off- the-shelf, low cost UHF TV circuitry, i.e. amplifiers and splitters. There is, however, the possibility for local UHF transmitters, mobile cellular radios and cable TV systems interfering with satellite reception since all share the same frequency band. Using the higher frequency 950 to 1450 MHz range avoids all potential problems with interference but higher cost components having higher cabling losses are required.

Block downconversion can be accomplished by an LNB or an LNA/block downconverter combination. The only difference is that the LNB combines the two functions in one box.

H. SATELLITE RECEIVERS

The video receiver selects a channel for viewing and processes the satellite signal into a form acceptable by a television or TV monitor. The downconverter, considered to be part of any receiver, is a matched component even though it is almost always located in a separate box out-doors at the dish.

The modern satellite receiver, which is light, small and attractively packaged, is the control station for a home satellite reception system. Gone are the days when video receivers were large, clumsy devices whose weight was almost a measure of cost.

All video receivers share the same basic task in preparing the signal captured by a microwave dish for viewing on a TV or listening on a stereo. However, just as one may drive to the theater in a Porsche or a Volkswagon, so consumers can select from among basic or highly sophisticated equipment.

How Receivers Work

A video receiver consists of a downconverter, final IF stage, discriminator, video and audio processor and, in most cases, a built-in modulator.

Downconverter

This stage lowers the frequency to a final IF, typically 70 MHz and accepts a voltage from the tuner to select channels as described in the previous sections. Receivers use either single, dual or block downconversion formats. The block downconversion methods have the advantage of allowing use of multiple receivers for simultaneously viewing of different channels on two or more televisions.

Final IF Stage

This stage, which usually operates at a final IF of 70MHz, is composed of a bandpass filter and an amplifier. The bandpass filter sets the channel bandwidth at 36 MHz or less by selectively eliminating any out-of-band signals. The amplifier restores losses incurred during downconversion stages and strengthens the signal for the next stage.

Detector/Demodulator

The detector/demodulator circuits process the FM modulated satellite TV signal into a form called the baseband signal. This baseband signal has all the original audio and video information contained in approximately a 10 MHz bandwidth. This baseband signal is used as input to stereo processors and decoders.

Two popular types of demodulators each having advantages and disadvantages are in use today. The phase locked loop (PLL) is more capable of detecting weak signals and of discriminating between the desired signal and interference. Less expensive PLL circuits can exhibit a tendency to produce slightly fuzzy video. In more extreme cases, bright colors or high contrast scenes will tear or streak and the picture may flicker. The coaxial delay line is not as effective in discriminating between the satellite signal and interference and of detecting marginal strength signals as the PLL. However, when signal strength is adequate, this type of demodulator delivers sharp, crisp pictures with well defined colors.

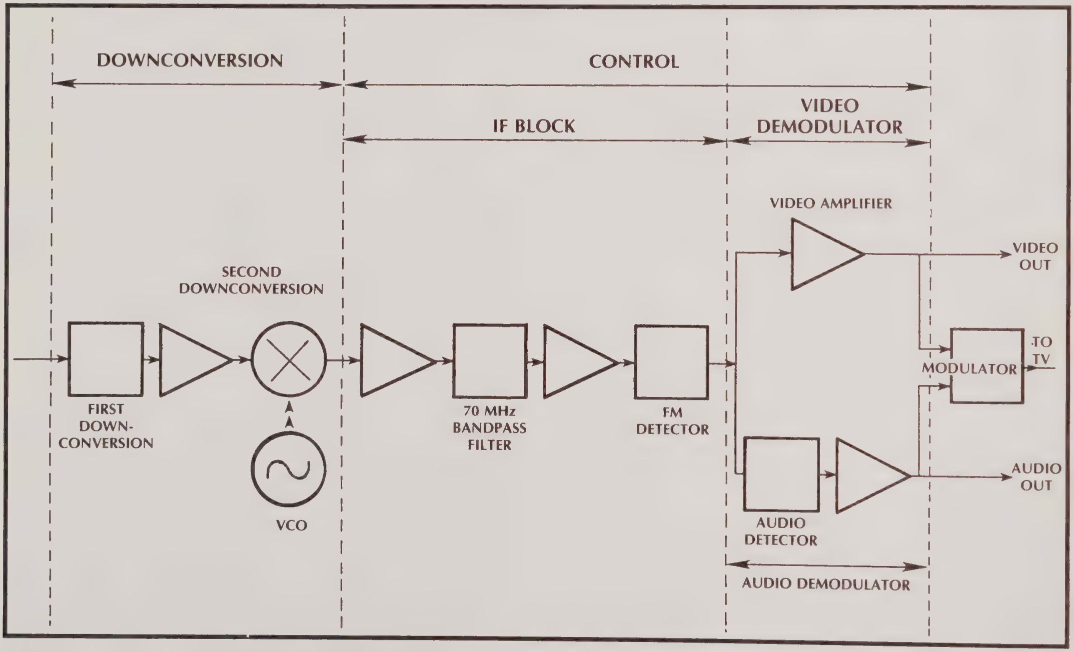


Figure 2-42. Receiver Schematic. *A satellite video receiver is responsible for electronically recapturing the original video and audio signals.*

Video and Audio Processors

The video processors removes a 30 Hz signal called the energy dispersal waveform and, in more advanced designs, tracks and corrects black and white levels in the video signal. The dispersal waveform was added to satellite broadcasts by order of the FCC. It gives these signals a distinguishable identity from terrestrial microwave sources sharing the same frequency band.

The video processor delivers the 0 to 4.2 MHz baseband video information to an amplifier. The audio processor selects audio information ranging in frequency from 30 to 15,000 KHz from a selected subcarrier. Satellite transmissions relay audio signals on subcarriers ranging from 5.0 to 8.0 MHz. The audio information required to supplement TV pictures is usually carried on a 6.8 MHz subcarrier which can be selected by a knob on the receiver front panel.

Modulator

A modulator is required to "rebroadcast" the raw audio and video signal in an AM form which can be understood by a conventional TV. Off-air channels, unlike FM satellite signals, are amplitude modulated. The selection of modulation frequency determines which television channel will receive the satellite programming. Channels 3 and 4 are typically selected.

How Receivers Select Channels

Every satellite is capable of relaying up to 24 television channels plus many audio subcarriers per channel. A video receiver selects any channel by first directing the probe rotation circuits to choose the desired polarity.

The tuner sends a voltage to a VTO either at the dish as is conventionally the case or to the correct circuit in the block downconversion receiver. This voltage causes the VTO to generate the proper mixing frequency for channel selection and then plucks the 36 MHz wide channel band down to the final IF. Earlier receivers and some commercial models today are set on one frequency; some semi-agile receivers permit channel selection by interchanging frequency-set crystal oscillators on their back panels. All home satellite receivers are fully agile.

Channel selection falls into two categories: detent; and synthesized tuning. Detent tuners can use either a continuously variable device such as a potentiometer (eg. Avcom or Anderson receivers) or a switch which clicks between various preset resistors (eg. Drake 324 or Uniden 1000) to send the required voltage to a VTO.

Synthesized tuners store the required mixing frequency in more stable devices than resistors. For example, both the Houston Tracker IV Super Plus® and V have a microprocessor which generates the correct frequency. The Maspro uses crystal oscillators specifically designed to send the exact frequency to the mixing circuits. Such higher quality synthesized tuners are much less subject to drifting between satellite channels than are detent tuned receivers.

Note that just because a botton is pushed instead of a knob being turned on a receiver to select channels does not necessarily mean that synthesized tuning is being used.

Judging Receiver Performance

The quality of a receiver is ultimately judged by clarity and fidelity of the television picture and crispness of the sound. These are measured by the video bandwidth, receiver threshold and tuning method used. These, in turn, are all determined by the care taken in designing and manufacturing as well as the choice of circuit components.

Video Bandwidth

Satellite broadcasts are relayed with a full 36 MHz bandwidth. However, a watchable television picture can be reproduced using only a 15 MHz bandwidth. Both fidelity and clarity vary with bandwidth.

Picture fidelity worsens as receiver bandwidth is narrowed. Picture details are slowly lost and color shades begin to vary. However, receivers having more narrow bandwidths also detect less noise power so unwanted "sparklies" are avoided. Thus clarity can be traded off for picture fidelity. It has been found that the picture quality using a 24 to 28 MHz bandwidth is virtually indistinguisable from that with a 36 MHz bandwidth. So this lower bandwidth has been adapted as an industry standard for satellite receivers. Home satellite receivers often use a bandwidth more narrow than 28 MHz to minimize noise. Some brands even come equipped with a front-panel adjustable bandwidth knob, a very desireable feature.

The judgement of what constitutes reception quality is of course very subjective. Consumer studies in which picture quality was rated according to signal to noise ratios show that although judgements vary, they are related to receiver threshold.

Receiver Threshold

The threshold of a video receiver determines how weak an input signal, measured by the carrier power to noise power ratio (C/N), can be before a picture is judged unacceptable. The concept of C/N can be clearly understood by imagining yourself in a room full of people. If everyone was speaking and the noise level was high, someone would have to shout to be heard. If it were so quite that you could hear a pin drop, a whisper at much lower audio power would suffice.

If the C/N fed into a receiver is plotted against its output signal to noise power ratio, S/N, a straight line results. This linear relationship means that for a given change in input, there

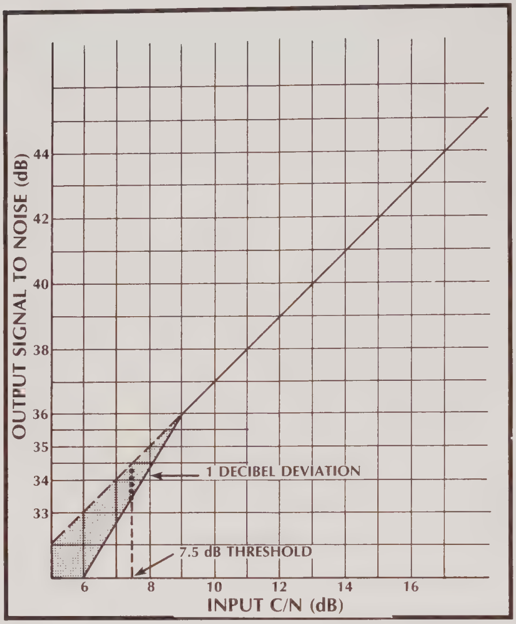


Figure 2-43. Receiver Threshold. *An earth station should provide a high enough C/N ratio to exceed receiver threshold. Threshold is measured at the point where the departure from linearity is 1 decibel.*

is a proportional change in output. To illustrate, if an input of 1 watt results in an output of 5 watts, then an input of 2 watts creates a 10 watt output. A simple example shows why this linear relation between input and output is important. A photograph of a scene having one area twice as bright as another would not look proper if the reproduced picture had that area only 50% brighter, or if the reproduction was not linear.

Threshold is measured at that point where the deviation from a linear or straight line plot is one decibel. Near or below threshold "sparklies" begin to appear. Subjective quality studies have shown judgements of picture quality as follows:

TABLE 2-9. PICTURE QUALITY AND RECEIVER THRESHOLD (Threshold Chosen as 8 dB)

Decibels Above or Below Threshold	Picture Quality
5	Extremely noisy, tearing, audio noise
6	A little better, sparklies
7	Watchable but sparklies
Threshold	A few sparklies
9	Very good picture; sparklies on only saturated colors
10	Video tape quality
11	Cable TV quality

Most home satellite receivers have thresholds at C/Ns of about 8 decibels, which is the value chosen as an example in this table. Referring to the table it is clear that a signal of 5 dB would generate an unacceptable picture.

"Extension" techniques are available to reduce video threshold. Using the best possible circuit components that contribute the lowest amounts of noise to a signal being processed is by far the most effective method. A second method is to reduce video bandwidth. This results in some loss of picture fidelity. Another method uses a circuit that not only switches on and reduces bandwidth when the signal is too weak for clear reception, but also "tracks" and centers its reduced bandwidth around the frequency where the signal is the strongest. These bandwidth and automatic frequency centering fixes may not work in some cases. For example, if a strong interfering signal is present the circuit may track the wrong signal.

Electrical Connections

Hooking up a video receiver is relatively simple. All receivers have a IF input from the downconverter and a RF output to televisions. Both these terminals almost always use standard F-connectors. Three polarity selection circuit wires, ground, pulse and 5.7 volts DC, are usually attached via screw connections. A separate set of appropriate screw connectors for a DC motor polarity selection device is sometimes also provided. If the receiver has a built-in actuator, then the four or five motor and counter terminals must be attached. Downconverter power connections vary. Some receivers relay downconverter power over the IF line; some use two wire screw-on connectors.

Other output terminals are available. The unprocessed baseband signal, the composite or un-filtered video, is usually accessible for relay to a stereo processor or descrambler. Some receivers with built-in stereo processors do not feature this output but should. Such receivers must have two RCA-jacks or their equivalent for connecting the left and right audio channels for relay to a stereo receiver. Often a RCA-jack output is provided to allow connection of an external signal strength meter.

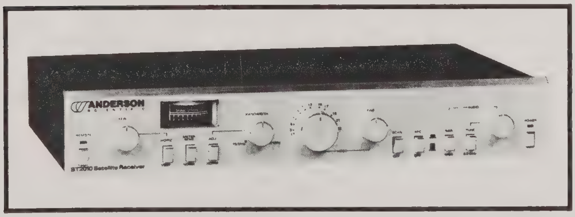


Figure 2-44. Variable Bandwidth Receiver. *This Anderson 2010 block downconversion receiver includes a control for reducing receiver bandwidth from 36 to 15 MHz. This may be useful in environments with moderate amounts of TI on sone channels. (Courtesy of Anderson Scientific, Inc.).*

User Interfaces and Adjustments

All receivers feature some standard controls incuding power on-off switch, channel selection, audio sub-carrier selection, polarity and skew adjustment, and, usually, video fine tuning. Many other controls occur on various brands. These include switches or buttons to selcet stereo format, channel scan mode, narrow/wideband audio filters, and video bandwidth control. Some receivers come equipped with signal strength meters and, occasionally, frequency contering meter.

However, the trend has been towards simpler customer interfaces. Some receivers are now available which automatically fine tune both the video and skew and have no customer interfaces to do so. Programmable units are completely controlled via simple-to-operate, hand-held remotes (for example, the Chaparral Sierra® receiver).

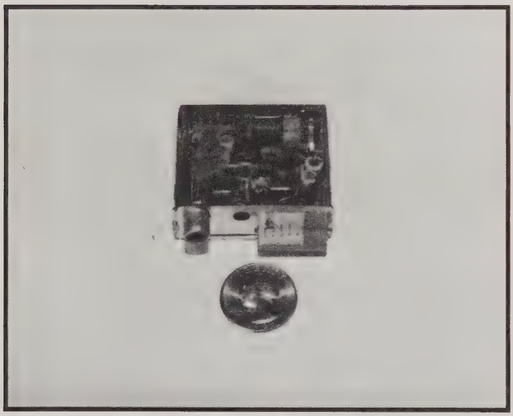


Figure 2-45. A Home Satellite TV Modulator. *Courtesy of Amnec, Inc.).*

Modulators

A modulator is a "rebroadcast" device which processes the satellite baseband signal into an amplitude modulated form acceptable by television sets. It is essentially an interpreter taking the baseband signal and translating onto an AM carrier frequency that a television has been designed to receive.

This baseband signal, which contains all the video and audio information required to recreate a television picture, can be fed directly into a TV monitor without use of a modulator. However, a conventional TV, has built-in demodulation circuits designed for picking up off-air broadcasts. Unlike a TV monitor, it can accept only remodulated signals. Note that higher quality reception will probably be attained with a monitor by eliminating these redundant steps. A home video cassette recorder (VCR) also processes the raw baseband signal and has its own built-in modulator driving a conventional television. VCRs can make higher quality tapes from satellite baseband signals than from demodulated and remodulated off-air broadcasts.

Baseband signals can be modulated onto any chosen VHF (channels 2 through 12) or UHF (46 channels television frequency. Most home satellite systems use a modulator, built into the video receiver, that feeds signals into either channel 3 or 4. If these channels are occupied by local off-air broadcasts, satellite signals can be modulated onto any other chosen channels. Then all satellite programs can be selected by leaving the TV set on this channel and controlling all selection via the receiver. The FCC allocation of all 58 TV frequency slots is listed in Table 2-10 for comparison purposes.

Home satellite receiver modulators are adequate for residential purposes. A more complex commercial system, such as a satellite master antenna design for a large apartment complex, uses a different arrangement. Each receiver is set to a given satellite transponder and has a dedicated external modulator tuned

to any chosen UHF or VHF television channel. These modulators are of higher quality and are more expensive than those built-into home receivers. The signals are combined at the "headend" and relayed to all the subscribers on a common cable. Then customers can select desired channels on their conventional TV sets by turning knobs or buttons.

A cable company system is designed somewhat differently. Like a commercial system each receiver has a dedicated modulator. But channel selection is accomplished by a separate device called a converter which sits next to the TV set. These channels are usually transmitted at mid- or super-band and the converter modulates them to channel 3 or 4.

Amplitude modulation was chosen for off-air broadcasts and later for cable TV relays because relatively high signal power levels are available, as is required for AM, and also because the transmission bandwidth must be maintained at a relatively narrow 6 MHz to permit a maximum number of channels per cable line. This system is different from that used in satellite FM broadcasts where wide bandwidth transmissions of relatively low power are used.

TABLE 2-10. VHF AND UHF TELEVISION CHANNELS

Designation	Channels	Number of Channels	Frequency Range (MHz)
Lo-VHF	2 to 6	5	54 to 88
FM Radio			88 to 108
Aeronautical			108 to 120
Midband	A to I	9	120 to 174
Hi-VHF	7 to 13	7	174 to 216
Superband	J to W	14	216 to 300
Hyperband	AA to WW	23	300 to 438

J. TELEVISIONS

The purpose of a television set is to recreate the original broadcast picture and sound as accurately as possible. A picture is created by an electron beam scanning across a screen of phosphor dots. The more intense the electron beam, the more illumination is produced for the viewer. This organized scanning occurs whether or not a video signal is present. When a video signal is received, it varies the scanning beam intensity and the resultant changes in illumination produce a picture. Without a video signal, the television screen will have a random but uniform pattern of dots ranging from black to white.

Thus a picture is "painted" line by line onto the face of a television. Information about each line's brightness (luminance) and color (chroma and hue) is translated into the video signal for interpretation by the TV. Scanning begins at the top left- hand corner of a screen. Following each horizontal scan (one line), the beam is turned off as the line is traced back to the beginning of the next one. When the bottom of the picture is reached the beam is again turned off. These "down times" are called the horizontal and vertical blanking intervals, respectively. During these periods other information on the

Figure 2-46. A Commercial Grade Modulator. *This crystal controlled modulator has an internal vestigial bandpass filter to reduce adjacent channel interference and a 35 dBm output level. It has F-connector input and output and is available in channels 2 through 13 and A through I. (Courtesy of Nexus Engineering).*

video signal such as teletext or captions for the hearing impaired can be relayed.

Synchronization signals are also an important component of the video signal. The horizontal sync sets the start of the horizontal scanning; vertical sync the timing for the beginning of vertical scanning.

Broadcast Formats

Various standards have been adapted worldwide setting the number of scan lines and the timing of their occurance of a TV screen. For example, the standard used in France called SECAM and the PAL format in many other countries, scans 625 lines 25 times each second compared to 525 lines 30 times each second in the American format. As a result, their pictures are "cleaner" and a little closer to movie quality but tend to have an annoying flicker because of the slower scanning rate.

The various video formats are examined in more detail in the next chapter. Here we examine only the NTSC (National Television System Committee) standard used for color TV in the U.S., Canada and Japan. Note that TVs capable of switching between video formats are available especially since the introduction of sophisticated digital television, TVs on a chip.

NTSC format has 525 lines scanned 30 times each second. In order to eliminate flicker, an interlaced method of scanning is used whereby two fields each having half of 525 lines, or 262.5 lines, are alternately impressed upon the screen 60 times each second. The total number of lines traced each second is 15,750 (60 times 262.5 or 30 times 525). Two sequential fields thus equals one frame.

The composite video signal is composed of the video signal, the blanking information and horizontal and vertical synch pulses. The video signal contains brightness (luminance) and color (chrominance) information.

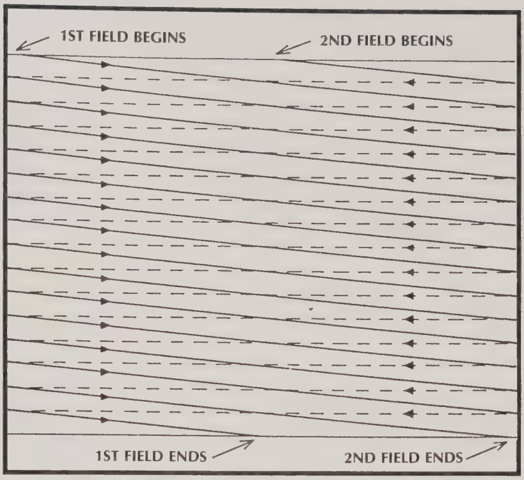


Figure 2-47. TV Interface Lines. *Pictures are scanned onto a television screen starting from the top left and ending at the bottom right. Two sequential fields are equal to one frame which is scanned 525 per second in the NTSC format.*

High Definition Television

High definition television (HDTV) is a new form of high resolution TV presently under development by Japanese as well as American companies. It uses 1150 scan lines instead of the conventional 525 in the NTSC format. The first probable adapted use will be in high powered direct broadcast applications in the Ku-band where newly designed equipment will be more easily introduced.

How to Judge TV Quality

Satellite broadcasts are capable of producing near-perfect quality video on an excellent television. Picture clarity and fidelity can even be remarkably good on an older, noisy set. Probably the best method used to judge TV quality is by eye, that is by actually view a satellite program on the set.

A better picture will be obtained on a TV which has been design well and manufactured with the best available components, and which is adjusted properly. The most overlooked adjustment which should be done in the field is to fine tune the center frequency of the channel used for satellite modulation. This channel has often not been used so the TV set may not be fine tuned.

TV Monitors vs. Conventional TVs

TV monitors are driven by the raw video, the video signal reduced to its lowest common denominator. A monitor is a conventional TV without a tuner section. The monitor usually provides a much sharper picture because these components unavoidably add some extra noise.

Tuning between Channels

Conventional TVs accept amplitude modulated (AM) video signals and then select channels by a tuner. The FCC has been careful not to allocate adjacent channels in broadcast areas. If this were not the case, some "bleedover" between channels could occurs.

When satellite signals are modulated onto channels next to off-air broadcasts, problems can occur. If the tuner is not high quality and if the satellite video signal has not been passed through a good bandpass filter, this bleedover or interference between channels characterized by "herringbone" or "venetian blind" patterns could occur. This bleedover can be overcome in a number of ways. A simple A/B switch with 60 decibels of isolation or more can be used so that only satellite or off-air television is fed into the television at one time. Or a signal combiner which has a built-in

bandpass filter, usually for channels 3 or 4, can be used to mix satellite and other signals. Obviously, a color monitor dedicated to just the satellite baseband output would be the simplest and most effective method.

K. STEREO PROCESSORS

The satellite baseband signal contains raw video and audio information spanning a band from near zero to 10 MHz. Since the video signal is contained in a more limited zero to 4.2 MHz range, a great deal of audio information can be carried in the remaining bandwidth.

Audio broadcasts are transmitted in the range from approximately 5.0 to 8.5 MHz on subcarriers. For example, if the stereo receiver audio frequency control knob is set to 6.2 MHz, an audio signal centered on this frequency not necessarily related to the television picture might be heard. To illustrate, Galaxy I, transponder 3 or Satcom 3, transponder 6 are loaded with audio subcarriers and transponder 18 on both Telstar 303 and Spacenet I is FM America audio dedicated for the home satellite TV enthusiast (for further information see "The Hidden Signals on Satellite TV"). The sound accompanying a video broadcast on a particular transponder is usually relayed on a 6.8 MHz subcarrier. Satellite TV is more appropriately satellite radio and television since so much audio information is carried along with the video.

The satellite baseband signal relays many of these radio stations and audio for some TV programs in stereo. Some video receivers have built-in circuits to process this stereo into a form where it can be fed into a home stereo receiver. Separate stereo processors can also accept the raw, unfiltered signal from a satellite receiver and prepare it for stereo listening.

Stereo Formats

There are presently four types of stereo formats. The discrete or brute force method transmits two separate subcarriers for the left and right channel sound. These subcarriers are located in the range from 5.0 to 8.5 MHz. For example, The Disney Channel on Galaxy I uses 5.8 and 6.8 MHz subcarriers for both audio tracks. A second more sophisticated discrete technique has been developed by Wegener Engineering and is used by the Disney Channel and the Nashville Network, among others.

The matrix method also requires two separate subcarriers. One channels contains the left plus right audio intelligence (L + R) and the second contains L - R. The stereo processor then algebraically combines the two to produce a stereo output.

The multiplex stereo system, patterned after FM stereo technology is somewhat more complex. Both audio channels are transmitted by one subcarrier on the baseband signal. It uses an FM subcarrier for the L +R audio signal, and a double sideband suppressed carrier for the L - R information. A 19 KHz synchronizing signal is also relayed for stereo demodulator reference to aid in recovering the original information. This signal reproduces either a monaural or stereo broadcast.

The FCC first selected this multiplex radio stereo broadcast method in 1961. In March, 1984, the FCC authorized conventional off-air TV broadcasts and this stereo sound format was suggested as a de-facto standard. However, multiplex stereo is rarely used in satellite broadcasts.

L. MISCELLANEOUS COMPONENTS

Satellite TV systems use a variety of smaller interface components such as A/B switches, matching transformers, signal combiners, splitters, line amplifiers, pads, DC blocks and terminators. These and other related components are examined in detail in Chapter V, Multiple Receiver Satellite TV and Distribution Systems.

Figure 2-48. A Stereo Processor. *This Astro Pro S-1000 stereo processor has the ability to select between mono audio as well as matrix or discrete stereo formats. Two knobs can independently tune through the audio frequency range. (Courtesy of Astro Pro. Inc.).*

III. SELECTING SATELLITE TV EQUIPMENT

The satellite TV business has evolved at an astonishing pace during the last five years. Today, selecting equipment for personal or customer use has become a matter of sifting through hundreds of antennas, receivers and other components. Five years ago, only a few brands of equipment were available and antenna actuators were virtually unknown.

In order to serve customers properly, a dealer must have a thorough understanding of the basics of satellite TV operation and then should keep track of new developments as well as of new equipment which is introduced at every major show. He or she must know what systems are least susceptible to terrestrial interference, how to properly design an earth station having an acceptable performance margin, what effects reducing spacing between satellites and weather will have on picture quality, as well as a host of other issues.

Learning all this information is not difficult, that is the purpose of this manual. It is simply a matter of reading word by word. But by far the most important and enjoyable task is acquiring crucial in-the-field experience.

Remember that this manual is not written to advertise various brands of equipment or to list everything on the market. There are ample trade journals which do that task perfectly well. Our intent is to provide the ammunition to allow a dealer to read and understand any trade journal or set of instructions in order to make well-informed judgements about the quality of satellite equipment.

A. THE BASICS OF SELECTING SATELLITE TV COMPONENTS

Among the criteria used in choosing components for satellite TV systems are performance, cost, features, durability and aesthetic appeal. Each of these must be weighed in selecting equipment for any customer. Some will be satisfied with a $1000 system having acceptable quality pictures on most but not all transponders; others will pay $6000 for an earth station having all the bells and whistles and will demand perfect video on all channels.

Mounts

The antenna and LNA are the most important parts of any satellite system. If not chosen properly, no extra money spent on receivers or other electronics known today will improve performance.

The antenna must be mounted on a stable foundation capable of accurately aiming a dish at the arc of satellites. A flimsy mount will allow an antenna to sway in the wind and may even collapse under the weight of a heavy snow. It must have a secure attachment to the supporting pole and mount, and a method for setting and maintaining declination and polar axis adjustments. The bearings which allow tracking should be well designed to move freely and to resist excessive wearing. The points of attachment to the dish must be strong but should not cause the antenna to warp or allow twisting or excessive movement under loads.

By far the best method to evaluate a mount is by examining its structure in detail. Push the dish from its outer rim to see if there is any play or if the various adjustments may be upset too easily. A comparison with other mounts is usually quite instructive. There are large differences between various brands.

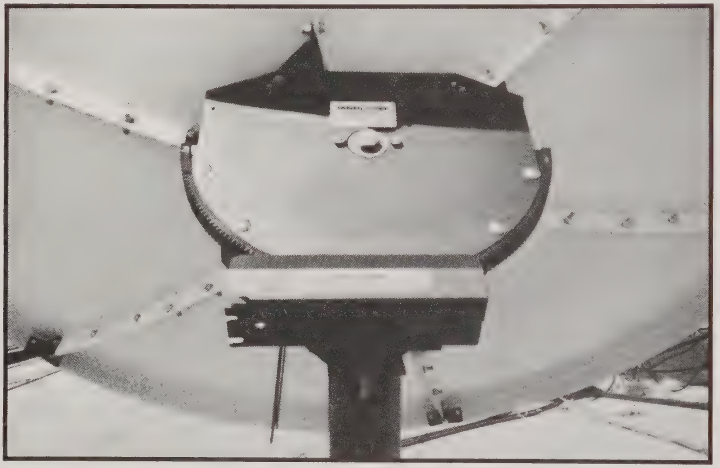


Figure 3-1. The Janeil Horizon-to-Horizon Mount. *This horizon-to-horizon mount displayed at a recent trade show rotates on a semi-circular track. (Courtesy of Janeil, Inc.).*

Actuators

Actuators arms and horizon-to-horizon assemblies are subjected to mechanical stresses. Jack tubes and motors are especially prone to problems and failures. However, satellite TV technology has developed over the last four or five years to the point where reliable units are readily available.

Make certain that the actuator jack of choice does not have excessive play. This could cause an antenna to flop around in the wind. A longer arm is need for a larger dish so that adequate leverage and force is maintained throughout its sweep across the entire arc. Seals against water entry should be thorough; drain holes should be drilled at the lowest point on the motor hous-

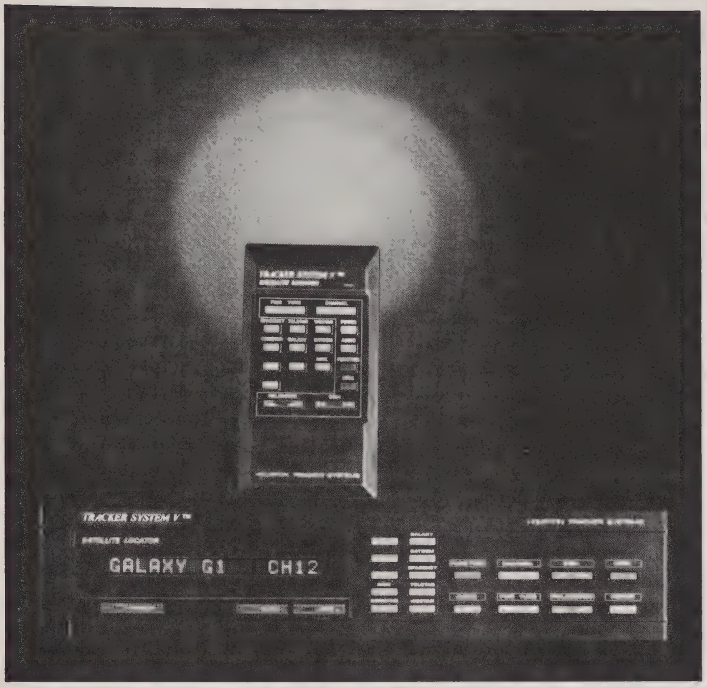


Figure 3-2. Houston Tracker V Actuator. *This actuator is operated by a UHF radio contolled remote (Courtesy of Houston Tracker, Inc.).*

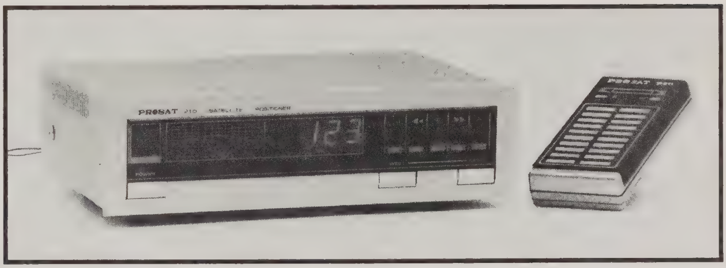


Figure 3-3. The Prosat 210 Actuator. *This is a basic east/west actuator with programmable limits. (Courtesy of Prosat, Inc.).*

ing. Actuator arms units should be shipped with ball joints for attachment to the dish and mount. Also make sure that the hardware is properly protected against the weather; galvanized, stainless or zinc-plated steel is the best.

Actuators are controlled from in-doors by signals from either potentiometers, Reed switches, Hall effect transistors or optical sensors, each type having somewhat different characteristics. Some actuators take an undue amount of time to send a dish from one end of the arc to the other. For the customer's sake be aware of the programming requirements for the actuator controller. Some brands are easy to install and program; others are more difficult and can be unreliable. Do not purchase an actuator which does not have electrically programmable limits or the ability to protect itself with devices such as slip clutches in the motor should some over-ambitious customer or confused microprocessor try to drive it far beyond the end of the arc.

Antennas

Antennas are the eyes of a satellite system. They must accurately concentrate and reflect the satellite signal as well as reject interference and noise. This is a tall order considering that a dish sits out-doors subjected to all the elements including corrosion, wind, ice and snow loading, hail, heat, cold and children. Of course, a dish that may be perfectly adequate in Florida may not stand the test of time in Wyoming where snow and winds are often excessive.

A simple, physical inspection of a dish can be very revealing. First, when sighting along one rim, does the other side line up perfectly parallel? If not, the dish is warped. Second, does it feel smooth to the touch or is the surface rough or bumpy? If the surface has visible waves or has panels or mesh sections that do not line up accurately, beware. Third, how is the hub or central portion of the dish attached to the mount? Check that the mount is adequately strong and well attached to the dish to support its full weight without allowing the antenna to sag and warp in time. Some dishes are secured with only a few screws or bolts which may twist as well as rock when it is under stress. These may not withstand the test of time in very windy or snowy environments. Any rocking or twisting movement caused by wind will eventually produce metal fatigue and lead to failure and poor video quality.

The design and method of supporting the feed assembly is very important. Check how much weight is hanging out in front of the antenna. Some designs resemble a bowling ball on a bamboo pole. They certainly should be supported by guy wires attached to the outer antenna rim. The feed should block a minimum amount of the dish aperture or side lobes may be unnecessarily high.

The designs and materials of a dish must be adequate so expansion and contraction caused by temperature changes will not ruin surface accuracy or structural integrity. If a panel is damaged it should be inexpensive and simple to replace. If the dish is located near an ocean, the materials must be treated to resist the highly corrosive effects of salt spray.

Other important criteria used in selecting an antenna are its weight, ease of shipping, assembly and appearance. If a dish will be installed on a roof mount, it makes sense to use a lightweight mesh or spun aluminum reflector.

Dishes can be grouped into two major categories: mesh and solid (for more details see Chapter II). The solid antennas are either fiberglass, or stamped or spun metal. Brands from each category can be evaluated by all the above criteria as well as by some which are specific to a given type of dish.

Mesh antennas can be made from perforated, expanded or stamped steel or aluminum. These materials are protected by painting, powder-coating or anodizing. Judging which methods are best for the given climate depends upon where the dish will be installed. A painted mesh dish may be perfectly durable in a desert environment but a disaster on the coast of Oregon because of salt corrosion. It is important that a mesh dish feel strong to the touch. A flimsy mesh will probably not withstand a hail storm without dimpling, deforming or having some panels badly damaged or destroyed.

How the shape of a mesh dish is maintained is crucial to its performance and is often related to the ease of assembly. As few as 8 or as many as 24 supporting stuts and panels of mesh may be used. Struts are usually manufactured from tubular steel, or extruded or angular aluminum for structural strength in order to maintain their shape when under wind or snow loading. In some mesh dishes, the actuator arm attaches to just one rib which certainly must be strong in order to maintain a true shape. If not, the antenna could be warped from one side. Mesh dishes often have one outer circular ring connecting these supports to the middle hub ; others have one or more middle supporting cir-

cular rings as well. Some designs and materials yield an accurate and stable surface; others are poorly designed and manufactured. Common sense judgements of these designs are usually surprisingly accurate.

Solid antennas are usually stronger and often can be more durable than mesh dishes. They can be assembled more quickly. Snow and ice tend to slide off instead of accumulating as is the case with some mesh antennas. But solid dishes usually weigh more and are more subject to wind loading and sagging under weight.

Spun aluminum or steel dishes do have the most accurate surface but are one piece and rather cumbersome to ship and to move to a site. This type of dish as well as the stamped or hydroformed variety must have their surfaces protected from rusting or oxidation. Of course, those that are made from stainless steel are free from this concern. But unpainted stainless steel dishes can have problems with heat build-up. In some brands, the mount is bolted to a back plate that is attached to the reflector surface. Others have mounts which are bolted directly to the back of the reflector and, if not carefully assembled, can distort the dish surface as the bolts are tightened. This is especially so if the mount does not properly match the reflector shape and if rubber washers, which can act as shock absorbers, are not provided for insertion between the mount and reflector. There can also be an electrolysis action between the different metals which can cause severe corrosion.

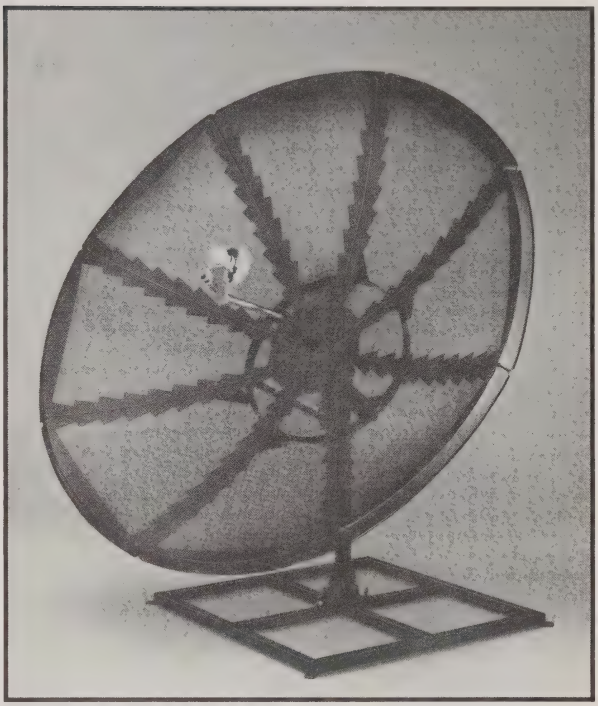


Figure 3-4. Perforated Steel Mesh Dish. *This 9 foot dish is an accurate reflector of microwaves and has aesthetic appeal. (Courtesy of Laux Communications, Inc.).*

The quality of a fiberglass dish depends upon which manufacturing method was used (see Chapter II for more details). If they are cured and molded properly, fiberglass antennas can have a very accurate, smooth surface. Improper techniques can result in warpage, shrinking, surface deterioration and even separation of the protective gel coating from the underlying structure. In the worst cases, the embedded reflective material could even delaminate. Fiberglass dishes can be very heavy and must have solid mounts attached securely at numerous points (see Figure 2-19). Like other types of antennas, sections should have compound curves and rib structures to form a true parabola and these should fit snuggly together. The surface should also feel smooth to the touch.

Fiberglass antennas have the advantages of being easy to assemble, corrosion resistant and durable. The best test of any brand of fiberglass dish is probably how it will maintain its accuracy and structural integrity over a period of time in the field.

The surface of any dish should be finished so that rays from the sun will not be reflected

and focused to potentially burn up the feed and LNA. Either dark or matted paints can be used because they diffuse light. Even rolled mesh and fiberglass surfaces are smooth enough to cause a problem unless they are properly painted.

Feed Supports

Prime focus parabolic antennas have two varieties of feed supports: buttonhook and tripod. Whatever type is used, the feed must be stable under wind or snow loads and should not move when the dish tracks across the arc. Make sure that both the attachments between the dish and support structure and the support and feedhorn are strong. A feedhorn, LNA and block downconverter mounted at the dish focus can easily stress their mounting hardware and cause the feedhorn to move from the desired "sweet-spot" at the exact phase center of the reflector.

Some dishes have feeds which simply pop into a preset position so that no adjustment of the focal length is possible. This is both an advantage and a limitation depending upon the attention an installer wish to give to tweaking the feed position. The adjustable varieties are more difficult to work with but allow additional fine tuning which can optimize the picture quality received.

Feedhorns

Feedhorns have the important job of properly illuminating a dish and of capturing as much of the incoming signal as possible. It is critical

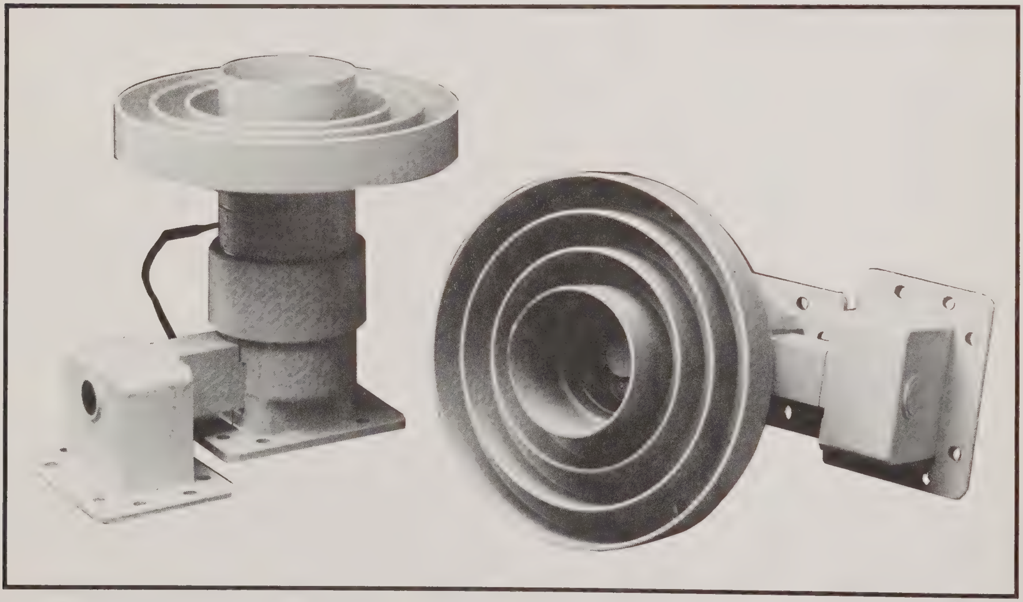


Figure 3-5. The Sidewinder™. *This dual feedhorn offers total skew adjustment capability in concert with the flexibility of a dual feed. (Courtesy of Chaparral Communications, Inc.).*

that the proper feed be chosen for each f/D ratio. Deep dishes (f/D from 0.32 to 0.25) will use different feed configurations than shallow ones.

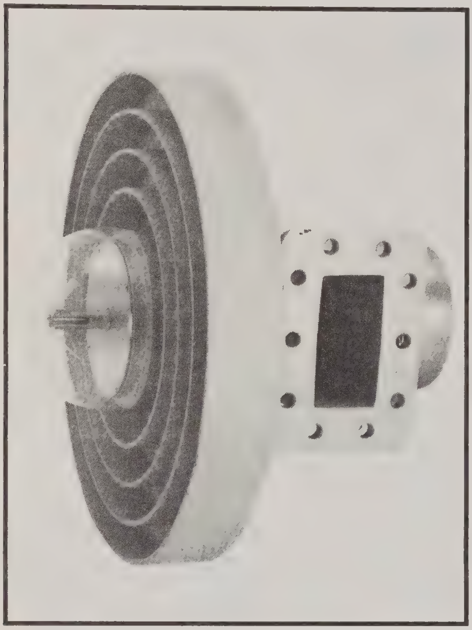


Figure 3-6. Seavey High Gain Polarizer. *This polarizer is designed for use with deep reflectors with f/Ds ranging from 0.25 to 0.35. (Courtesy of Seavey Engineering Associates, Inc.).*

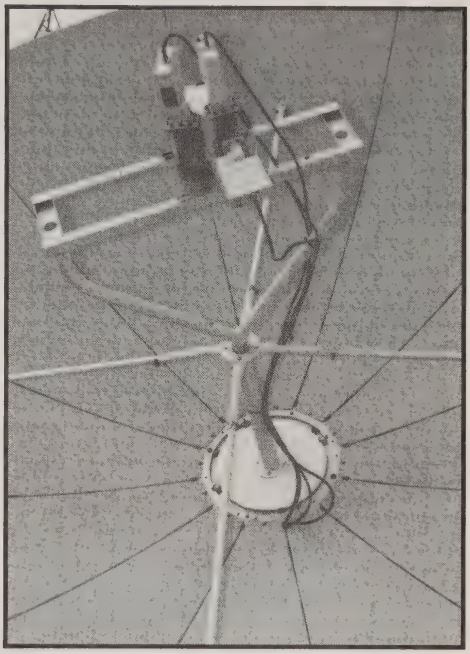


Figure 3-7. Multiple Feed System. *This 4 meter Scientific Atlanta dish is equipped with four LNAs attached to two dual feedhorns. These feeds can be adjusted to simultaneously detect two satellites separated by a range of angles up to 12 degrees. This configuration is almost always used in commercial installations.*

Well designed and manufactured feeds have very low insertion losses, i.e. they transmit most of the signal into the LNA. The selection of a feedhorn can be an important determinant of picture quality. The cost is a small enough portion of the entire system cost to warrant purchasing top of the line equipment.

Polarity selection can be accomplished by mechanical rotors, ferrite devices or pin diodes. Each has its strength and weaknesses. For example, a ferrite device will probably perform more reliably in very cold climates where motors may seize. Pin diodes have some insertion loss and do not have the capability for skew adjustment. This may be perfectly adequate for large, fixed-antenna systems.

LNAs, LNBs and LNCs

LNAs are the most complex piece of an earth station but most often the most reliable. LNA noise temperature should be low enough to yield a good quality picture (see next section). An LNA gain of at least 40 decibels is desireable. For the slightly higher price tag, a 50 decibel gain LNA is good insurance against

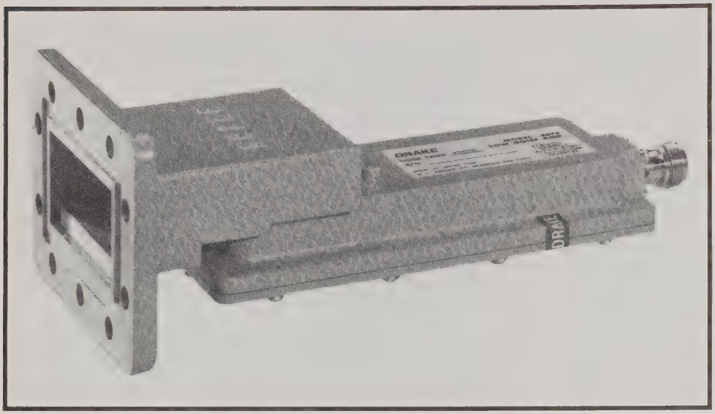


Figure 3-8. Drake LNA. *LNAs with a range of noise temperatures are available from manufacturers like the R.L. Drake Company. (Courtesy of The R.L. Drake Company).*

overly long cable runs. Using an LNA gives more flexibility than either LNBs or LNCs. If a problem arises, just the LNA can be easily swapped out for one with the same noise temperature.

Figure 3-9. Low Noise Block Downconverter. *The external differences between an LNA and an LNB are not noticeable except that the output is usually an F- instead of an N-connector. (Courtesy of California Amplifier, Inc.).*

LNBs are becoming commonplace. In situations where independent channel selection on multiple receivers will be used, an LNB is by far the best choice permitting the design of a simple, low cost system. Since LNBs transmit an intermediate frequency higher than the more common 70 MHz IF, lower loss cable may have to be used for long runs. LNBs have one important disadvantage. Since the low noise amplifier and first downconverter are contained in one sealed box, notch or bandpass filters can only be inserted in three places. A microwave bandpass filter can be installed between the feedhorn output and the LNB input. Notch filters, one for each interfering carrier, can be inserted between the LNB output and the receiver. Or filters can be placed in the final IF loop at the receiver.

LNCs are rarely used. These amplifiers are like LNAs in not being suitable for multiple receiver, independent channel selection systems and, being exposed to the elements, can suffer from channel drifting. LNCs are also more costly to replace than LNAs. Note that LNBs are easier to install than LNAs and LNCs. Only one RG-6 or RG-59 cable is required.

Receivers and Downconverters

Sometimes it seems that there are as many receivers available as salesmen to sell them. And each brand of receivers has a different look and occasionally different features. The first step in selecting a receiver is determined by the choice of LNA, LNB or LNC, since these must be mated to the receiver. Once this hurdle has been crossed the next step is to judge video quality.

Video quality can vary substantially between receivers. Some will produce jumpy, flickering or grainy pictures. These characteristics are a reflection of receiver electronic design. If a low threshold has been obtained by the least desireable method, reducing the bandwidth, the result is often fewer sparklies but a picture with less resolution and smeared colors. Phase lock loop (PLL) receivers will normally have lower thresholds than coaxial delay line receivers. However, in more extreme cases when using PLL receivers, bright colors or high contrast scenes can tear or streak. But when using undersized antennas, PLL receivers can have thresholds 1 to 2 dBs lower than coaxial delay line types and therefore better pictures.

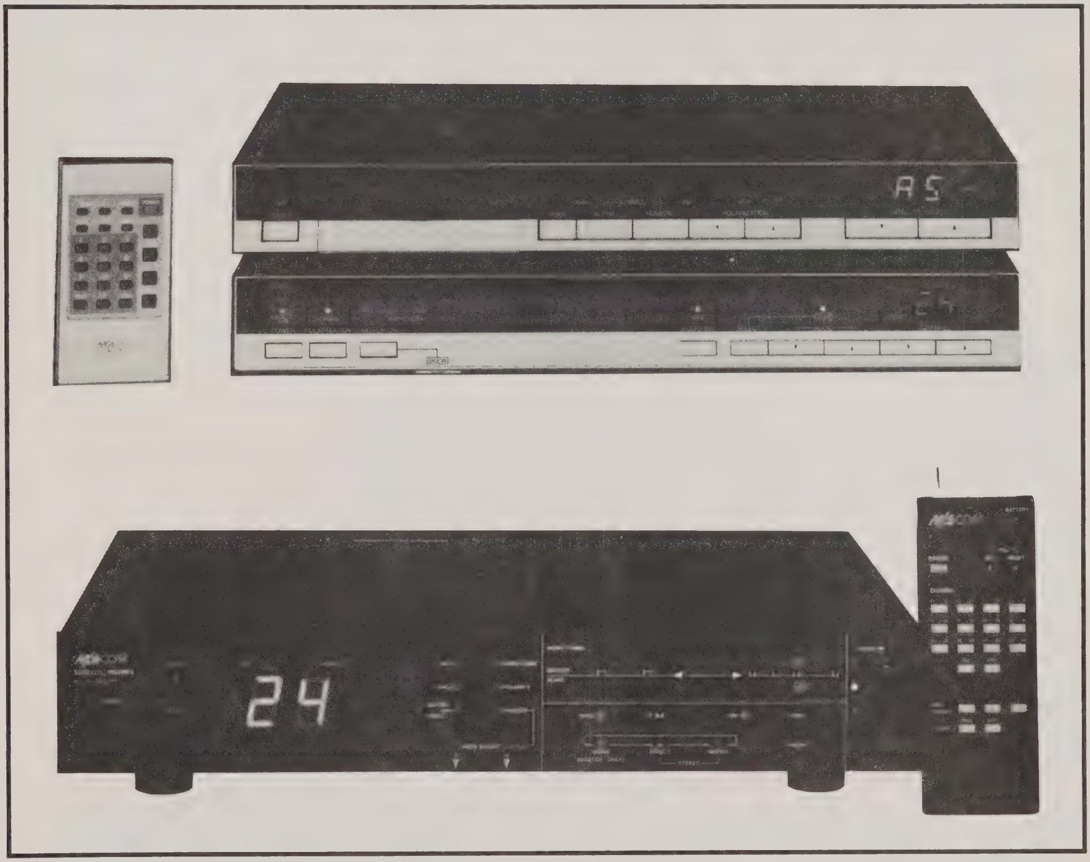


Figure 3-10. M/A COM Recievers. *The M/A COM T1 and H1 receivers can be purchased with matching component actuators. (Courtesy of M/A COM Home Satellite Systems).*

Audio quality can also vary. The audio should be easy to tune over the full 5 to 8.5 MHz range. There should be no buzzing or rasping on weaker transponders with bright colors on the screen. Check both the video and audio quality on transponders which are loaded with audio subcarriers. Each audio subcarrier should be heard clearly and crisply providing the signal strength is adequate.

Receivers also differ in their method of tuning between channels. Continuously variable tuning may be quick but it can be annoyingly inaccurate and determining what channel has been selected may be difficult. Some receivers have an even/odd polarity selection button. This prevents the polarizer from rapidly switching back and forth as all channels are scanned in their natural order, i.e. 1,2,3,4, etc...

If a remote control is desired for the master receiver, it should have the five main functions: channel selection; fine tuning; audio selection; volume control; and polarization selection. If any of these were absent the customer would have to walk over to the receiver to change the missing function thus eliminating the advantage of the remote control. Some of these functions could be automatically selected by the receiver.

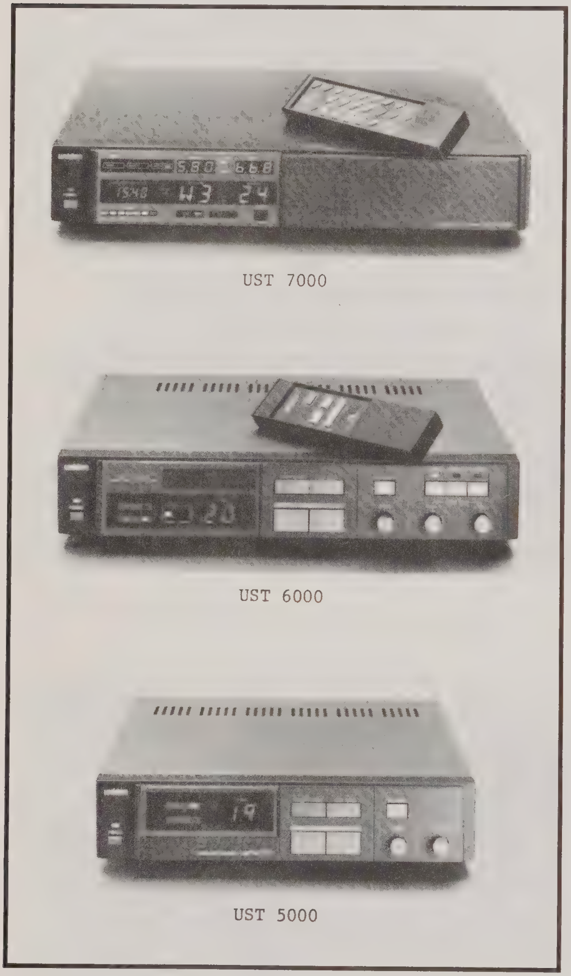


Figure 3-11. Uniden Video Receivers. *These three receivers are all block downconversion having a 950 to 1450 MHz IF. The 6000 include a built-in stereo processor; the 7000 has, in addition, a built-in antenna actuator. (Courtesy of Uniden Coporation).*

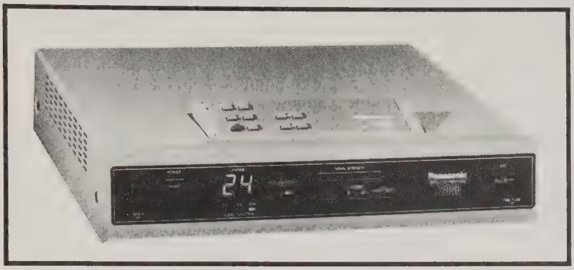


Figure 3-12. Panasonic C-2000 Receiver. *This infrared remote controlled receiver uses a 950 to 1450 MHz block downconversion LNB provided with the unit. (Courtesy of Panasonic).*

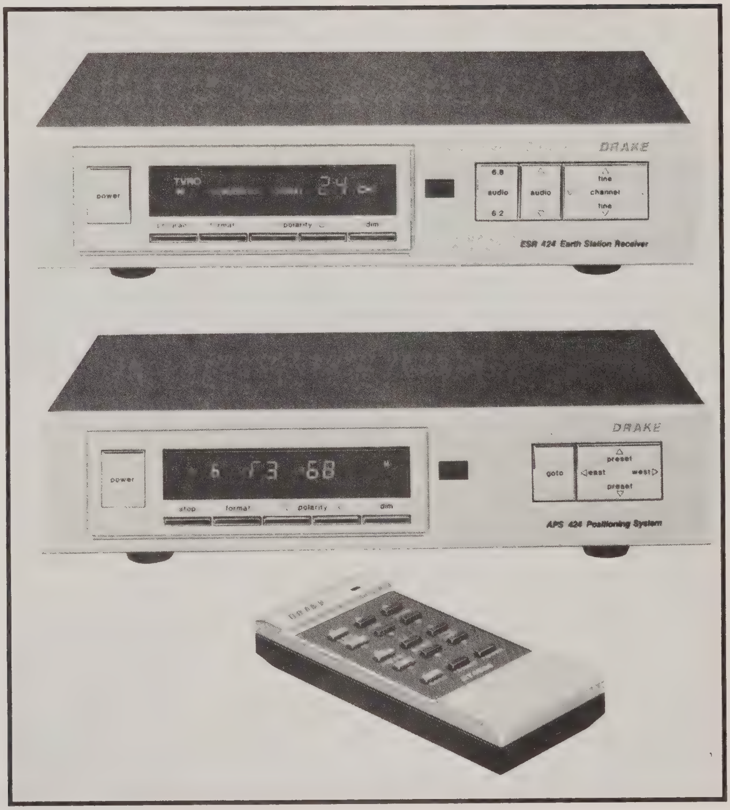


Figure 3-13. Drake 424 Receiver and Actuator. *The Drake receiver is available in both single and block downconversion (950 to 1450 MHz) models. Like many other recently introduced actuator/receiver combinations, one infrared hand-held remote controls all functions. (Courtesy of the R.L. Drake Company).*

Figure 3-14. Viewstar VSS1450 Receiver. *This receiver has quartz synthesized audio and video tuning, 950 to 1450 MHz IF block downconversion, a built-in east/west antenna actuator and stereo processor , and infrared remote control. (Courtesy of Viewstar Corporation).*

Figure 3-15. Kenwood KSR-1000 Receiver. *The Kenwood remote IR controlled, block receiver (950 to 1450 MHz) has digital synthesized audio and channel tuning. Its stereo processor chooses between the three modes, multiplex, discrete and matrix. (Courtesy of Kenwood Electronics).*

Figure 3-16. MSL Switchable Downconverter. *This dual purpose block downconverter can be switched between the two of the most common block downconversion frequency ranges 950 to 1450 MHz or 450 to 950 MHz. (Courtesy of Micro Scientific Labs, Inc.).*

TABLE 3-1. SATELLITE RECEIVER SURVEY								
Manufacturer/Model	Features							
	Tuning	Meter	Remote Control	Built-In Actuator	Automatic Polarity Selection	Block Down-converter	Stereo	Ku-Band
Amplica CSR100	PB	x						
Amplica CSR200	PB	x	IR					
Amplica CSR300	PB	x	IR	x	x			
Amplica CSR1000	PB	x	IR			x		
Anderson ST910	V					x		
Anderson ST1010	V	x	IR			x		
Anderson ST2010	V	x	IR			x		
Arunta 418-Interceptor 2	PB	x	IR	x	x	x	x	
Arunta Q429 Invader	PB	x	IR		x	x		
Avcom COM-2A	V	x	W					
Avcom COM-2B	V	x						
Avcom COM-3	D	x	W		x			
Avcom COM-3R	D	x	W		x			
Birdview MR2020	PB		W		x	x	x	
Boman SR1200	V	x			x			
Boman SR1500	V	x			x		x	
Boman SR1600	V	x			x	x	x	
Boman SR2500	PB	x	W	x	x		x	
Channel Master 6131	V	x				x		
Channel Master 6129	PB	x				x		
Channel Master 6134	PB	x	IR		x	x		
Channel Master 6136	PB	x	IR	x	x	x	x	x
Chaparral Sierra	PB	x	IR	x	x	x	x	x
Conifer 2001	D	x	W	x				
Conifer 2002	D	x	IR	x	x			
Curtis-Mathes KSR-330	PB	x	IR	x	x		x	
Draco Aimer 5	PB	x	IR	x	x	x	x	
Drake SR 324	D				x			
Drake ESR 324-block	D				x	x		
Drake ESR 424	PB	x	IR		x			
Drake ESR 424B	PB	x	IR		x	x		
DX DSB 600	D	x			x	x		x
DX DSB 700	PB	x	IR		x	x		x
Electrohome E-1	PB		IR	x	x	x	x	
GI System 950	V				x	x		
GI System 1000	PB	x	IR		x	x	x	
Gensat BSR-1200	D	x			x	x	x	
Gensat CDR	4/12	x	IR	x	x	x	x	x
Geo-Tech 2001R	PB	x	IR		x	x	x	
Geo-Tech 8300	V	x						
Geo-Tech 9600	PB	x	IR		x			
Hamilton SV-420	PB	x	IR		x			
Houston Tracker System V	PB	x	UHF	x	x	x	x	
Hytek SRX500	PB	x	IR	x	x	x	x	
Janeil BCR-2000	PB	x			x	x		
Janeil BCR-5000	PB	x	IR		x	x		
Kenwood KSR-1000	D	x	IR		x	x	x	
KLM SBR 6100	PB	x	IR	x	x	x	x	
KLM SBR 2100	V	x				x	x	

	Tuning	Meter	Remote Control	Built-In Actuator	Automatic Polarity Selection	Block Down-converter	Stereo	Ku-Band
KLM Sky Eye 10	V	x						
Lowrance 70-XB	D	x	W			x		x
Lowrance 70-SB	D	x	W			x	x	x
Lowrance 70-S	D	x	W				x	
Lowrance 70-X	D	x	W					
Luxor 9539	PB				x		x	
Luxor 9550	PB		IR	x	x		x	
Luxor Mark II	PB	x	IR	x	x		x	x
M/A COM T1	PB	x	IR		x	x	x	
M/A COM T2	PB	x	IR		x	x		x
M/A COM H1	PB	x	IR		x	x	x	
M/A COM 2000R	PB	x	IR		x	x		x
M/A COM T6	PB	x	IR	x	x	x	x	x
Maspro SR-2D	PB	x	UHF		x			
Maspro SR-3	PB	x	UHF	x	x	x	x	x
Nikko Audio SR-300R	PB	x	IR		x	x		
Norsat JR-100	PB	x		x	x	x		
Norsat JR-200	PB	x	IR	x	x	x	x	
Norsat 300R	PB	x	IR		x	x	x	
Cosmos 2	V	x			x			
Panasonic C-2000	PB	x	IR		x	x		
Panasonic KV/C-6000	PB	x				x		x
Regency SR-5000	PB	x	IR	x	x	x	x	x
Regency SR-3500	V	x				x		
Sat-Tec XR-1	PB	x	IR		x	x	x	
Sat-Tec R-5100	V	x			x	x		
Sat-Tec R-7000	V	x			x		x	
Sat-Tec 5000XL	V	x			x			
Scanner SR 1000	PB	x	IR		x	x	x	
STS LSR	PB	x	IR	x	x	x		
STS SRb	D	x			x	x		
STS MBS-SR Block	PB	x	IR		x	x	x	
TDP TDP-500	PB	x	IR	x	x	x		
Toki TR99	V	x						
Toki 110S	V	x					x	
Toki TR 150B	V	x			x	x		x
Toki 220	PB		IR					
Toki TR-330	PB		IR	x			x	
Uniden UST-1000	D	x			x			
Uniden UST-3000	D	x	IR		x			
Uniden UST-5000	PB				x	x	x	
Uniden UST-6000	PB	x	IR		x	x	x	
Uniden UST-7000	PB	x	IR	x	x	x	x	
Viewstar VSS 1450	PB	x	IR	x	x	x	x	x
Wilson YM 450	V	x			x	x		
Wilson YM 1000	PB	x	IR		x			
Winegard RF-90	V	x			x	x		
Winegard RF-1000	V	x	IR	x	x			
Winegard RF-0800	V	x	IR		x			
Winegard RF-0600	V	x			x			

Key:
V - variable
D - detent
PB - push button

IR - infrared line-of-sight
W - wired remote
UHF - wireless radio remote

Stereo Processors

Stereo processors, either built into a receiver or stand alone, should be capable of handling at least the two most popular stereo formats: discrete; and matrix. The separation between channels should be clear and distinct and the audio quality should be strong and clean with no popping or static audible. There are two ways to tune in audio channels. The first uses a continous tuning circuit such as a potentiometer. The second and the most accurate method is voltage synthesized tuning. All audio channels are preprogrammed into a memory and selected at the push of a button as displayed by a digital readout.

Television Monitors

Television monitors accept raw audio and video signals from a satellite receiver and bypass the intermediate modulation step. As a result, picture quality can be better compared to conventional television sets. A satellite dealer may find a good quality monitor useful as a demonstration of how clearly satellite broadcasts can be received and as an installation tool. Table 3-2 lists some of the monitors available for purchase today.

Warrantees

Even the best designed and manufactured equipment can fail. If the factory offers a warrantee having too short a period, does not provide a fast turnaround on service or, even worse, is out of business when this equipment fails, a dealer can incure considerable costs.

The typical warrantee for satellite TV components offers full coverage for at least 90 days and limited coverage for one year. But there are wide variations. A few manufacturers have extended warrantees on electronic equipment lasting up to 2 years. And some antenna manufacturers warrantee their products for five years indicating either faith in their design or an unrealistic hope in the longevity of their product. In any case, responsible manufacturers should stand behind their products with prompt service. But realize that companies have been known to go out of business when high equipment failure rates overly taxed their financial resources. In these cases, their warrantees were only as good as the paper they were written on.

Therefore, a prudent course of action to follow should include careful selection of well-made equipment, a knowledge of the underlying warrantees and an evaluation of the manufacturer's stability and reputation. Word-of-mouth information from knowledgeable sources can be invaluable in judging a manufacturer.

TABLE 3-2. TELEVISION MONITORS

Model	Screen Size (inches)	Channels	Video In/Out	Features	Cost ($)
NEC CT-1901A	19	134	2/3	3-source switching; 1 day/1 event & sleep timer; simulated stereo; headphone jack; external speaker terminals; 5 W/channel amplifier.	700
NEC T-2020A	20	142	2/2	Flat, square picture tube; sleep timer; 3-source switching; on-screen channel/time display; headphone jack; ext. speaker terminals; 5 W/channel amplifier.	780
NEC CT-2501A	25	134	2/2	Same as NEC CT-1901A	850
Panasonic CTF-2075R	20	139	3/3	Flat,square picture tube; 4-source switching; on-screen channel/time and function display; sleep timer; headphone jack; external speaker terminals; 5 W/ch. amp.	1000
Panasonic CTF-5379R	25	139	3/3	Same as above with conventional picture tube.	1100
Proton 619-S	19	82	2/1	4-source switching; headphone jacks; 3.5 W/channel amplifier.	700
Proton 619	19	127	2/1	Same as above.	850
Quasar TT-6299XW	20	139	3/3	Flat,square picture tube; 5-source switching; sleep timer; on-screen channel/time display; headphone jack; external speaker terminals; 8 W/channel amplifier; built-in stereo decoding.	1000
Quasar TT-9908XS	25	139	3/3	5-source switching; sleep timer; on-screen channel/time display; headphone jack; external speaker terminals; 8 W/channel amplifier; built-in stereo decoding.	1100
Quasar TT-9909XS	26	139	3/3	Flat, square picture tube; 5-source switching; sleep timer; on-screen channel/time display; external speaker terminals; 8 W/ch.amp.; built-in stereo decoding.	1250

RCA GKC-2040	25	127	2/0	3-source switching; on-screen channel/time display; TV/VCR remote control; built-in stereo decoding.	1050
RCA FKC-2022	25	127	4/3	4-source switching; on-screen channel/time display; external speaker terminals; TV/VCR remote control; built-in stereo decoding.	1100
RCA GKC-2080	25	127	4/3	4-source switching; on-screen channel/time display; exteranl speaker terminals; TV/VCR remote control; built-in Stereo decoding.	1560
Sharp 20J-580	20	142	2/0	Flat, square picture tube; 4-source switching; sleep timer; on-screen channel/time/mode display; mono amplifier	760
Sony KV-20XBR	20	125	3/2	Fine-pitch Microblack screen; color temperature controls detachable flat speakers; on-screen channel/function display; simulcast switching; 5 W/channel amplifier; built-in stereo decoding.	900
Sony KV-25XBR	20	125	3/2	Same as above.	1200
Sylvania RXC-192SL	19	134	2/3	2-source switching; 3.58 MHz color trap; 1-day/1-event timer; video-in level control; headphone jack; simulated stereo; external speaker terminals; 5 W/ch. amp.	660
Sylvania RLC-312SL	25	134	2/3	Same as above.	890
Toshiba CZ-2074	20	133	3/1	Flat, square picture tube; 4-source switching; headphone jack; simulated stereo; external speaker terminals; 10 W/channel amplifier.	1000
Toshiba CZ-2084	20	133	3/1	Same as above with built-in stereo.	1050
Toshiba CZ-2094	20	134	3/1	Same as above without stereo but with digital chassis having screen-within-screen viewing.	1200

B. HOW SYSTEM DESIGN IS DETERMINED - LINK ANALYSIS

The choice of dish size and LNA noise temperature are determined by two factors: video receiver threshold; and the effective isotropic radiated power (EIRP) of a satellite signal. An analysis of the power levels radiated by a satellite, the dish gain and the overall system noise temperature, called link analysis, tells us everything we need to know.

Footprint maps are first used to determine EIRP or signal power aimed towards any location. The analysis must then account for the weakening of earthbound microwaves as they spread out in space and are partially absorbed by the atmosphere. The receiving antenna captures and concentrates these signals according to its gain. The job of deciphering satellite signals is more difficult the higher the system noise temperature, which is in large part determined by antenna and LNA noise temperature.

Very simply put, the link equations are as follows:

Carrier to noise power ratio reaching the receiver	=	Signal power leaving the satellite, the EIRP
		less
		The free space path losses and atmospheric absorption
		plus
		Antenna concentrating power or gain, G
		less
		Noise introduced by the LNA, antenna and other system components

or, in more condensed form:

$$C/N = EIRP - \text{Path Loss} + G - 10 \log T - 10 \log B + 228.6$$

This equation simply expresses the above words in algebra. The terms with the logarithm, log, are needed to convert the system noise temperature, T, and the signal bandwidth, B, into decibels. As bandwidth is increased more noise enters the system, so this is subtracted to show its effect on C/N. The last term is a constant.

Thus, if EIRP, path loss, bandwidth and required C/N are known, we can calculate G/T by addition and subtraction. Remember that the G/T is the figure of merit, or bottom line, or a antenna/feed system. This tells us the minimum antenna diameter and LNA noise temperature to use. So, as we would expect, each link in the satellite relay chain helps determine the requirements for all other links.

The EIRP is easily determined for any satellite by reading a footprint map. The path loss measures how much the satellite signal spreads out in space and how much it is absorbed as it travels though the atmosphere. This can be calculated or be easily read from the figure in Appendix C. Note also that absorption by the atmosphere increases with installation latitude angle since dishes in more northerly locations must look at a steeper angle through thicker layers of atmosphere to see the geosynchronous arc. Of course, during a rainstorm path loss will increase as water absorbs the microwaves. This is especially important for higher frequency Ku-band broadcasts.

A typical value for path loss is 196.3 dB. This means that a signal is reduced by a factor of 196.3 dB or 40 billion billion! This is not a typo; there is not an extra billion. Satellites are over 22,300 miles away in space and most

transponders have powers ranging from 5 to 8 watts. This is why satellite TV systems are so sensitive to added noise from the environment and electronic equipment such as the LNA.

System Noise Temperature

The system noise temperature is a measure of how much noise is added to a satellite signal by all parts of an earth station. This includes the noise detected by the antenna, the noise introduced by the LNA and the noise added by all the cable runs and remaining electronic devices including the downconverter and receiver.

In most terrestrial microwave applications the noise detected by the receiving antenna is small compared to that added by electronic equipment. This is because the signal power levels are relatively high. However, satellite relays are received at much lower power and are sensitive to noise from two sources: galactic noise or noise detected from outer space; and noise introduced by radiation picked up from a warm earth. Galactic noise varies is typically 4 K representing the very cold temperature of deep space.

The noise introduced by the warm earth is "seen" by a dish through its side lobes. The amount of noise detected depends upon both the side lobe patterns and the angle of elevation. The more shallow it points to a target satellite the more earth is seen. A higher quality dish will see less noise.

A graph of antenna noise versus elevation was presented in Chapter II, Figure 2-7. It can be used to find how much noise a typical antenna adds to a satellite system. For example, a 9 foot dish pointed at an elevation of 40 degrees above the horizon would detect about 35 K noise. Note that since the elevation to satellites at the center of the arc is higher than to those at the east and west edges, these southerly targets are seen with less added antenna noise.

The noise introduced by the LNA is simply the LNA noise temperature. Thus a 85 K LNA adds 85 K of noise to the earth station.

The noise added by the remaining components such as cables, the downconverter and the receiver is very small by comparison. This is because the LNA amplifies both the signal and the noise detected by the dish and LNA. The power amplified by the LNA is so much larger than the noise introduced later on that this additional noise is almost negligible. It usually adds no more than a total of 5 K extra noise temperature when using a 40 dB LNA or as low as 0.5 K using a 50 dB unit.

How Small Can a Dish Be?

It would be glorious if a two foot dish could be hung out from a window sill to receive C-band satellite TV. Unfortunately, this is not yet possible because the carrier-to-noise power reaching a receiver would be below threshold (and the beamwidth would be so large that five satellites would be detected at once). The link equations allow us to calculate realistic minimum dish sizes for use in a satellite receiving system.

If we substitute a typical value of -196.3 dB for path loss and a 28 MHz bandwidth into the C/N equation, then we find:

$$C/N = EIRP + G - 10 \log T - 41.68$$

The figure of merit of a dish/feedhorn/LNA, the G/T, written as G - 10 log T here, depends upon both the LNA and antenna noise temperature. So T is the sum of these two temperatures.

For example, assume a 10-foot dish having a 40 dB gain and contributes 36 K of noise is used with a 90 K LNA. The G/T is then given by:

$$G/T = 40 - 10 \log (90 + 36) = 19.0 \text{ dB}$$

So if we find that the EIRP is 34 dB at the location in question then:

$$C/N = 34 + 19.0 - 41.68 = 11.32 \text{ dB}$$

Since most satellite receivers have thresholds below 8.5 dB, this combination of a 10-foot dish and a 90 K LNA which yields a C/N of 11.32 dB is more than adequate to produce a quality picture.

What if a 6-foot dish were used with this 90 K LNA or a 6-foot dish were used with a 65 K LNA? The link equations show that C/N increases most quickly with antenna diameter. Decreasing LNA noise temperature also helps to raise the power reaching the receiver, but by a lower amount. Also, increasing LNA gain helps up to about 40 dB, but above 50 dB further increases have little effect on C/N.

To illustrate, assume EIRP is 34 dB, the satellite signal bandwidth is 28 MHz and an antenna having an efficiency of 60% contributes an extra 36 K of noise. Then the following table can be constructed by using link analysis and gain numbers from Table 2-2:

TABLE 3-3. HOW C/N VARIES WITH ANTENNA SIZE AND LNA TEMPERATURE

Antenna Gain (dB)	(diameter)	LNA Noise Temperature 65	75	85	90	100
35.54	(6 feet)	7.82	7.41	7.03	6.86	6.52
36.88	(7 feet)	9.16	8.75	8.37	8.20	7.86
38.04	(8 feet)	10.32	9.91	9.53	9.36	9.02
39.06	(9 feet)	11.34	10.93	10.55	10.38	10.04
39.98	(10 feet)	12.26	11.85	11.47	11.30	10.96
41.18	(12 feet)	13.46	13.05	12.67	12.50	12.16
43.68	(16 feet)	15.96	15.55	15.17	15.00	14.66

So a 7 foot dish with a 65 K LNA will have a greater C/N than a 8-footer with a 100 K LNA and will therefore perform better. It is clear that, to a certain extent, antenna size can be traded for LNA noise temperature. But it is important to realize that G/T is affected most directly by dish size. For example, a 16 foot antenna operating with a 100 K LNA has more than 3.3 dB improvement in performance over a 9-footer matched with even a 65 K LNA. This is more than 100% improvement!

There are two important facts to note. First, this does not account for the fact that smaller antennas have wider beamwidths and different side lobe patterns. The assumption that the antenna noise temperature is the same could be partially wrong, especially for a poorly constructed smaller dish. Also, deeper dishes tend to have lower noise temperatures than shallow ones.

Second, if a receiver having a threshold of 8.0 dB is used, a C/N of 8.0 decibels will be marginally adequate; sparklies will often appear. It is best to design a safety margin of at least 1 to 2 decibels into a satellite TV system. So if a torrential rainstorm strikes, the picture will not be lost in an on-the- screen snow storm of sparklies. Also, without an adequate margin

of safety, as satellites age and lose power picture quality would deteriorate.

So how small can a dish be? The final decision is made by knowing the minimum EIRP to be detected at the installation location, the video receiver threshold and the margin of safety to be used. The decision will also be influenced by factors such as the relative cost of decreasing dish size versus lowering LNA noise temperature, aesthetic judgements and site constraints on dish size and type. Of course, everything else being equal, a high quality dish will perform better than a poor one of the same size.

A final criteria to be used in determining dish size is how the customer rates picture quality. If a dish is installed in a rural area which previously had access to only one very noisy off-air channel, a somewhat sparklie picture may be greeted with joy. This same picture may be totally unacceptable to one who is used to receiving top quality cable TV channels.

Why a Performance Safety Margin is Needed

The concept of a safety margin is very simple. If receiver threshold is 8 decibels and a satellite system is designed to deliver a C/N of 8 decibels in calm weather what happens when strong winds blow. The resulting deflection of the dish off target can result in a loss of signal and picture detereoration. Or during a torrential rainstorm as much as 0.5 decibels can be lost at higher frequencies as rain absorbs the microwaves. Then a flurry of sparklies appear on the screen. The same result can occur as a satellite ages and its transponders weaken and EIRP drops or as a dish or mount sags and falls slightly off target.

A safety margin of at least 1 decibel for home systems and as high as 3 decibels for commercial systems should be designed into an earth station unless the customer understands that picture quality will occasionally be poorer on some stations or transponders. Some customers will be satisfied with this outcome, some will not. Note that some receivers automatically reduce their bandwidth as a signal drops near or below its normal threshold. This will result in poorer quality pictures, again a sign that enough margin has not been added to a satellite receiving station.

The bottom line is simple. A well designed system may cost a little more up front but will save a dealer from making extra, costly service calls. And satisfied customers mean referrals and more business.

C. SUSCEPTIBILITY TO TERRESTRIAL INTERFERENCE

Terrestrial interference, TI as it is unfondly known to satellite dealers, is caused when a satellite TV system detects unwanted earth-based signals. The effects on picture quality can range from a mild case of sparklies to complete wipe-out. Some forms of TI are easy to avoid or cure but severe interference can completely ruin reception of a satellite broadcast.

The good news is that learning to understand and combat 99% of TI cases is not difficult. And knowing when to turn down a job and walk away in those rare instances when TI can be solved only by throwing money away is very important. Many a dealer has lost hundreds or even thousands of dollars on that unforgettable installation. But like an outbreak of the acne,

TI cannot be ignored. It has been estimated that 10 to 20% of all new home satellite TV installations experience some form of TI, from mild sparklies to complete picture wipeout.

The most reasonable approach for combatting TI is a two stage strategy. First, TI is avoided by chosing the correct satellite TV equipment and by properly locating the antenna. If this fails, interference is suppressed by using a combination of filters and man-made shields. These methods are covered in more detail in the Microwave Filter Company's publication "The ASTI Manual - The Avoidance/Suppression Approach to Eliminating Terrestrial Interference." This is a highly recommended book for those wishing to explore TI is more detail.

Sources of TI

Interference originating from any signals sharing the band of frequencies which are used at any point in a satellite TV receiving system can potentially cause problems. This ranges from the microwave C-band and above to as low as the audio and video baseband range. Thus, if an unwanted 70 MHz signal leaks into a receiver, which processes satellite channels on the same frequency, pictures can deteriorate. Or, for example, if a communicator nearby is using an 980 MHz relay, the 950 to 1450 MHz block downconverter range might be affected.

The potential interference band can be broken down into two segments: the ingress interference band below 1 GHz; and the antenna interference band from 1 GHz to approximately 8 GHz. The difference between these two bands is that lower frequencies cannot enter via the antenna/feedhorn/LNA route while the microwave signals in the 1 to 8 GHz range can do so.

Note that methods to avoid or screen TI out with natural or man-made obstacles are not covered here. These will be treated in Chapter IV, How To Correctly Install a Satellite TV System.

The Ingress Interference Band

TI below about 300 MHz will probably enter through poorly grounded or improperly connected equipment. For example, a local TV station might be received along with the satellite TV signal if a ground connection is "float-

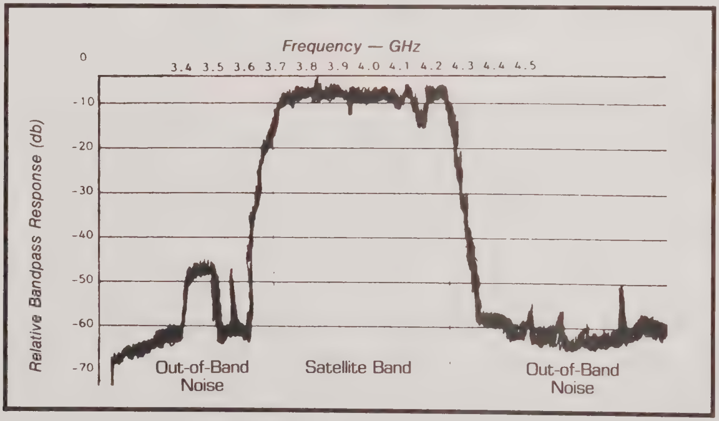


Figure 3-17. LNA With Built-in Bandpass Filter. *This illustration shows how frequencies outside the satellite C-band range are rejected by a bandpass filter. (Courtesy of the Microwave Filter Company).*

Potential Antenna Interference Frequencies

Frequency (GHz)		*Nature of Potential Offender*
0.960-1.350		Land-based air navigation systems
1.350-1.400		Armed forces
1.400-1.427		Radio astronomy
1.427-1.435		Land-mobile: police, fire, forestry, railway
1.429-1.435		Armed forces
1.435-1.535		Telemetry
1.535-1.543		SAT—maritime mobile
1.605-1.800		Radio location
1.660-1.670		Radio astronomy
1.660-1.700		Meteorological—Radiosond
1.700-1.710		Space—research
1.710-1.850		Armed forces
1.990-2.110	2	TV Pick-up
2.110-2.180	2	Public common carrier
2.130-2.150		Fixed point-to-point (non-public)
2.150-2.180		Fixed—omnidirectional
2.180-2.200		Fixed, point-to-point (non-public)
2.200-2.290		Armed forces
2.290-2.300		Space—research
2.450-2.500		Radio location
2.500-2.535		Fixed, SAT
2.500-2.690		Fixed point-to-point (non-public) Instructional TV
2.655-2.690		Fixed, SAT
2.690-2.700		Radio astronomy
2.700-2.900		Armed forces
2.900-3.100		Maritime radio navigation
2.900-3.700	3	Maritime radio location
3.300-3.500	3	Amateur radio
3.700-4.200	1	Common carrier (telephone) Earth Stations
4.200-4.400	3	Altimeters
4.400-4.990	3	Armed forces
4.990-5.000		Meterological—radio astronomy
5.250-5.650		Radio location (coastal radar)
5.460-5.470		Radio navigation—General
5.470-5.650		Maritime radio navigation
5.600-5.650		Meteorological—Ground based radar
5.650-5.925		Amateur
5.800		Industrial and scientific equipment
5.925-6.425	2	Common carrier and fixed SAT
6.425-6.525	2	Common carrier
6.525-6.575		Operational land and mobile
6.575-6.875		Non-public point-to-point carrier
6.625-6.875		Fixed SAT
6.875-7.125		TV pick-up
7.125-8.400		Armed forces
8.800		Airborne Doppler Radar

Interference frequencies listed in the order of occurrence on TVROs:

1 *Telephone carrier spectrum co-located with TVROs.*

2 *Widely distributed common microwave carriers.*

3 *Seldom occurring frequencies close to TVRO Band.*

Figure 3-18. Potential Antenna Interference Frequencies. *(Courtesy of the Microwave Filter Company).*

ing" and has not been properly attached. At frequencies above 300 MHz, wavelengths are short enough that signals can leak in through poorly shielded equipment cases or into any openings.

This type of interference is usually easy to cure by properly grounding cables, using wall plug filters, shielding of equipment interconnects and closing unnecessary gaps in metal equipment. It has the recognizable effect of causing similar problems on all satellite channels such as a characteristic picture defect or an audio buzz.

The Antenna Interference Band

Whereas ingress interference usually arises when an installation is not "perfect," TI entering through the front door, the dish, is possible even in the best installed system. The antenna interference band can be subdivided into two distinct regions: in-band TI centered on 3.7 to 4.2 GHz; and out-of-band TI spanning the 1 to 8 GHz ranging but excluding C-band frequencies.

The source of in-band TI is nearly always common carrier land-based, repeater station networks which share the C-band with satellite TV transmissions. These communicators carry voice, video and data traffic for a fee via the familiar microwave antennas situated on large towers scattered across the country. AT&T, Sprint, MCI, and Allnet are among the more well known but many regional and local common carriers also are in service.

These C-band networks have proliferated as telephone, data and other communication needs continue to grow. It is estimated that new license applications and requests for network modifications are being submitted at a rate of 30 to 50 every month. In total, the growth rate

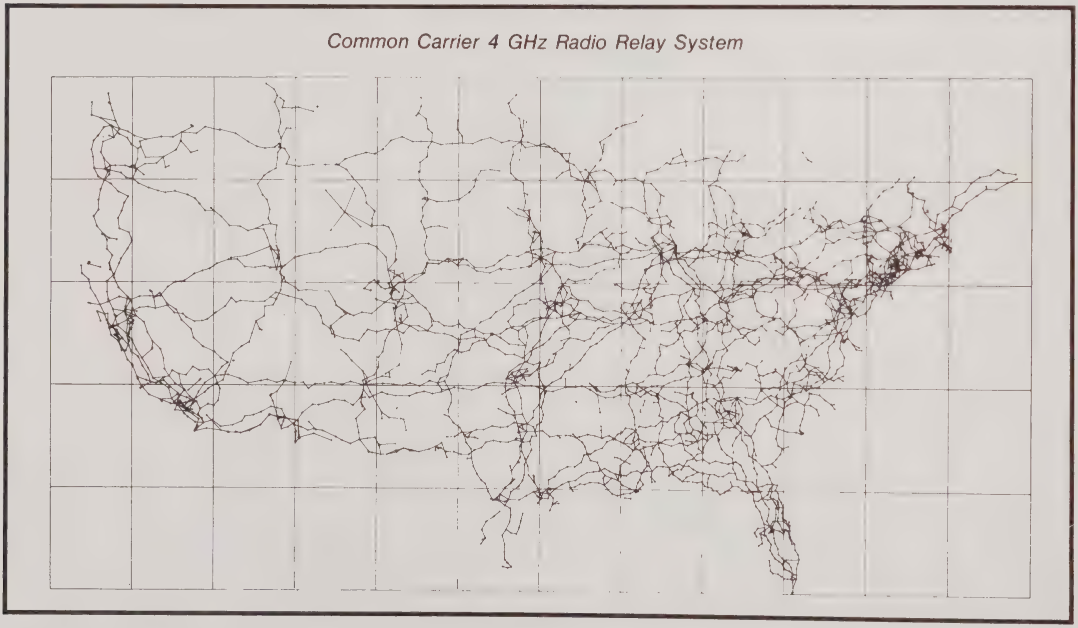


Figure 3-19. C-Band Common Carrier Network. *This map shows the locations of microwave towers and their links. The common carrier network has grown by about 40% since this map was drawn. (Courtesy of the Microwave Filter Company).*

is at least 10 to 20% yearly. Today, such networks crisscross the United States like a giant spider web centered on the major metropolitan areas and spanning rural regions. In-band TI accounts for about 95% of all interference problems.

Each antenna on a repeater station can carry up to 6 different frequencies of either vertical or horizontal polarization. And each tower can have multiple antennnas. In some areas, only one frequency is used; in others, all 25 possible common carrier channels may cause serious problems receiving satellite TV broadcasts.

The FCC wisely allocated these "Ma-Bell" transmissions different center frequencies than those used by satellite TV broadcasts. The allocated frequencies lie 10 MHz above and below the center frequency used by each satellite channel. For example, channel five is centered on 3800 MHz, so common carrier relay using frequencies of 3790 and 3810 MHz can be potential sources of interference. A total of 25 frequencies are assigned to common carriers; 23 between each channel and one each above and below the satellite range.

TABLE 3-4. COMMON CARRIER CENTER FREQUENCIES

Transponder Number	Satellite Center Frequency (MHz)	Possible Interfering Center Frequency (MHz)
		3710
1	3720	
		3730
2	3740	
		3750
3	3760	
		3770
4	3780	
		3790
5	3800	
		3810
6	3820	
		3830
7	3840	
		3850
8	3860	
		3870
9	3880	
		3890
10	3900	
		3910
11	3920	
		3930
12	3940	
		3950
13	3960	
		3970
14	3980	
		3990
15	4000	
		4100
16	4020	
		4130
17	4040	
		4150
18	4060	
		4170
19	4080	
		4190
20	4100	
		4210
21	4120	
		4230
22	4140	
		4250
23	4160	
		4270
24	4180	
		4290

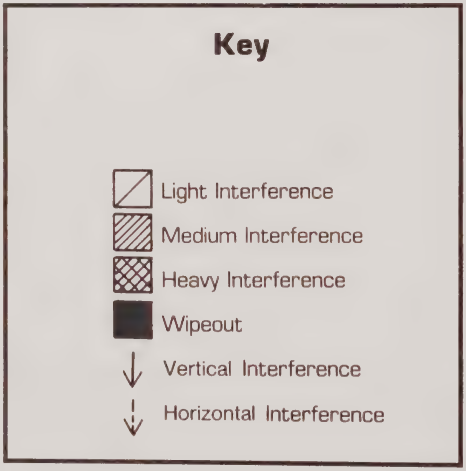
Common carrier relays usually use signals spread about 3 to 5 MHz around their center. These "narrow-band" transmissions typically for telephone links can often be easily "notched out" from the signal seen by a satellite receiver. However, "wide- band" formats often used for videoconferencing links and data service networks are becoming more commonplace. Such transmissions having 5 to 30 MHz bandwidths severely interfere with satellite broadcasts and cannot be eliminated with notch filters without destroying a great deal of the picture information. More expensive and sophisticated "phase cancellation" methods are required to overcome this form of TI.

Out-of-band TI have carrier frequencies that lie in the 1 to 8 GHz band. There are four major communications band accounting for most of the out-of-band TI.

TABLE 3-5. MAJOR SOURCES OF OUT-OF-BAND TI

1.990 to 2.110 GHz	TV studios relaying to relay towers and between metropolitan areas.
2.110 to 2.180 GHz 6.425 to 6.525 GHz	Common carrier bands for relaying data.
5.925 to 6.425 GHz	"Fixed SAT" for carrying remotely originated programs to uplink stations for satellite broadcasts.

Effects of TI on Satellite TV



Out-of-band TI has characteristic effects on satellite TV reception. It usually either causes all channels to be "bad" or shows up as a continuous group of "bad" to "good" channels from either end of the band to the other. In this case, an out-of-band interfering signal would affect those satellite channels closest in frequency. Thus, for example, if a strong 2 GHz signal were detected by a dish and transmitted into the receiver it would affect the lower channels most strongly. If this interfering signal happens to be horizontally or vertically polarized, it would most strongly affect those co-polarized channels. The type of picture deterioration is generally the same on all affected channels.

It is rare that weak to moderate out-of-band interference below 2577 MHz will affect a satellite receiving system. The WR-229

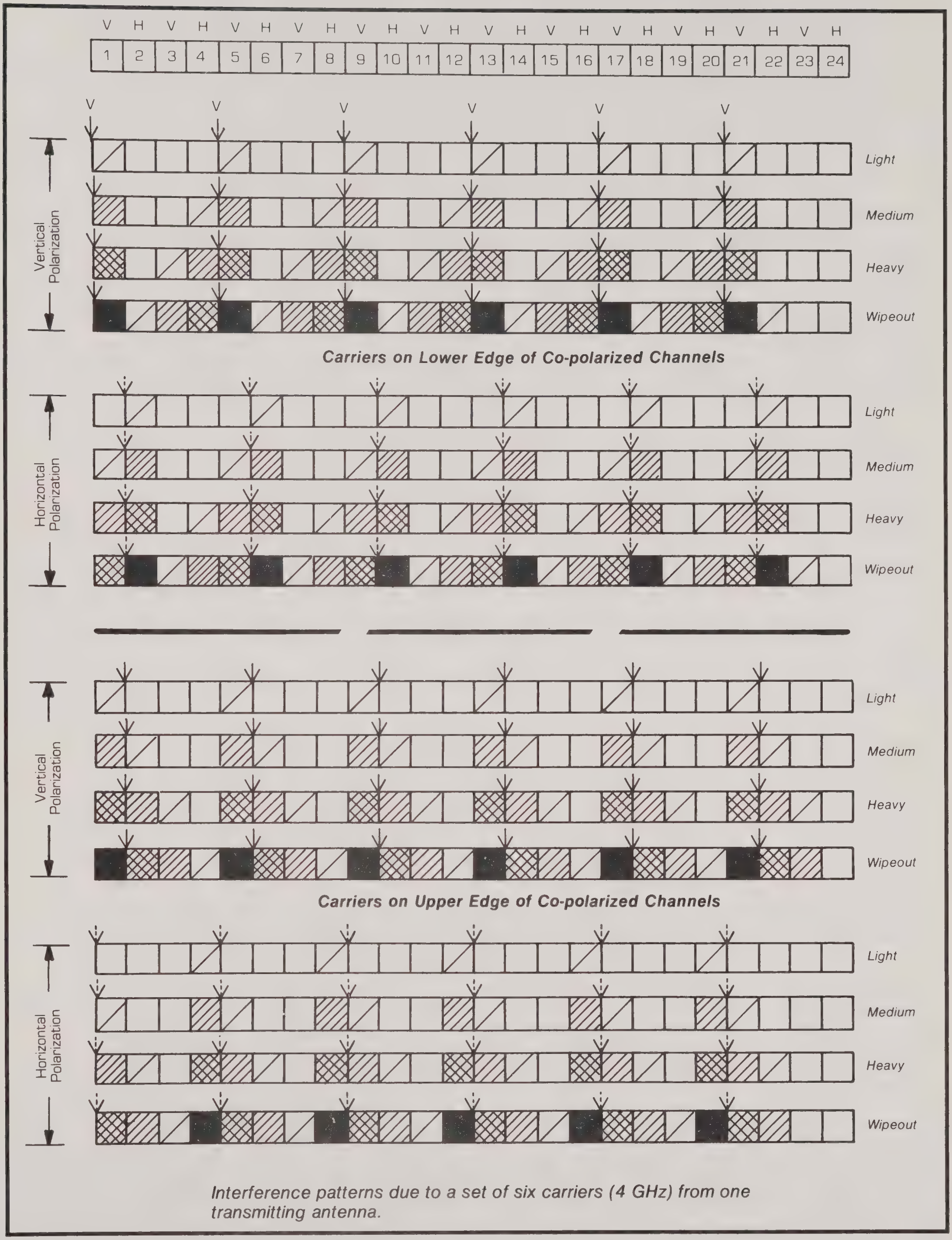
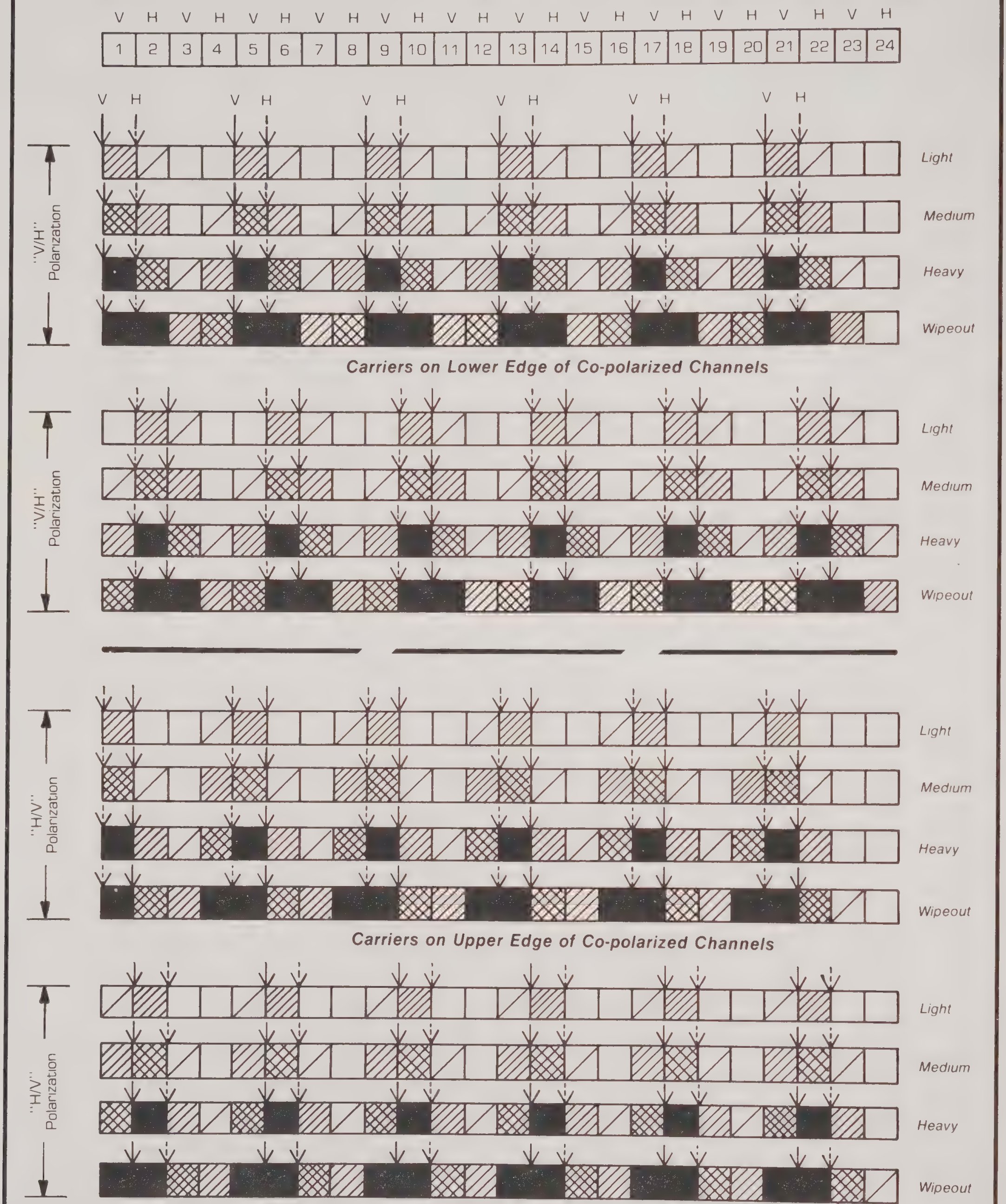


Figure 3-20. TI Patterns on Satellite Channels. *Both six and twelve carriers from one transmitting antenna show a characteristic regularity in patterns of channel disturbance. The key to reading both of these figures is shown on the left. (Courtesy of the Microwave Filter Company).*



Interference patterns due to two sets of carriers (six per set) due to two transmitting antennas of the same station.

waveguide flange on the LNA input severely attenuates signals having frequencies below 2577 MHz. However, very strong out-of- band signals can sometimes overpower the lower frequency cutoff of this waveguide and interfere with satellite TV reception.

Medium to heavy power out-of-band TI can usually be cured with a microwave bandpass filter placed between the LNA and downconverter. The bandpass designation means that the filter allows only those frequencies in a given band through and attempts to reject all others. However, if the interfering signal is high enough in power it may overdrive the LNA, known as driving it into compression. In this case, a special microwave bandpass filter would have to be inserted between the feedhorn and LNA to eliminate TI.

In-band TI also has characteristic signs. Repeater stations transmit up to 6 carriers of a given polarity spaced 80 MHz apart. Thus, if interference from one relay were intercepted, 6 satellite channels spaced 2 channels apart would be affected. If more than one transmitting antenna were used and if the earth station also detected those signals received by the repeater station having different polarity or frequency, all 24 channels could be affected. Usually, patterns of good and bad channels are seen. Even if all 24 channels were affected, the degree of interference would vary between channels.

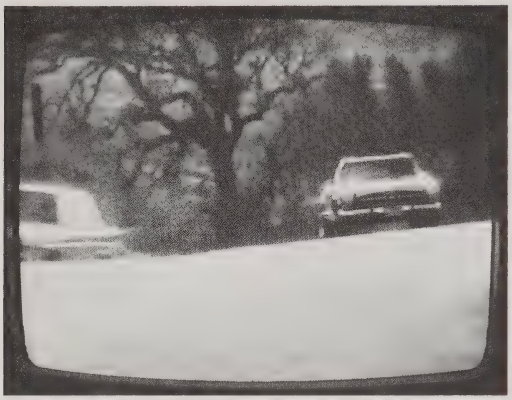
The effect that TI has on satellite television depends upon its power relative to the satellite signal. If it is 18 decibels below the desired signal then it is not noticeable on a TV screen. As TI powers rise to about -10 db sparklies begin to appear on the screen. These increase until about -3 db when the dots reach a "flurry" level. At 0 db, the "blizzard" level, the picture is nearly lost. Above this power, TI begins to detune the receiver; the automatic frequency control (AFC) circuit often begins to track the TI instead of the satellite signal. At +3 db the screen has a no detectable picture and a coarse appearance. At +5 db the screen is blank and uneven. Above +10 db the screen is completely whited out and has a fine, even texture.

Both wide-band and narrow-band TI have similar effects on satellite picture quality. But wide-band interference carries more power and therefore has more pronounced negative effects.

TABLE 3-6. RELATIVE TI LEVELS AND SYMPTOMS

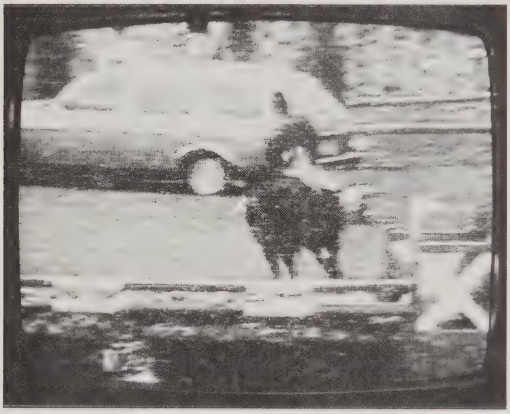
TI Relative to Satellite TV Signal	Symptom
Less than -18 dB	No Problems
-18 to -10 dB	None to Light Sparklies
-10 to -3 dB	Heavy Sparklies - Picture Barely Watchable
-3 to 0 dB	Lines or Random Pattern- No Picture.
Greater than 10 dB	Complete Wipeout

If the AFC circuit is disabled, usually with an external or internal receiver switch, the satellite frequency can be manually tracked. Then a watchable picture may be seen even with TI levels as high as 10 dB. Note that if a receiver has frequency synthesized tuning it must have a very "stiff" AFC circuit which deviates less than 3 MHz from the selected frequency. If not, it may track even lower levels of TI than a receiver normally would.

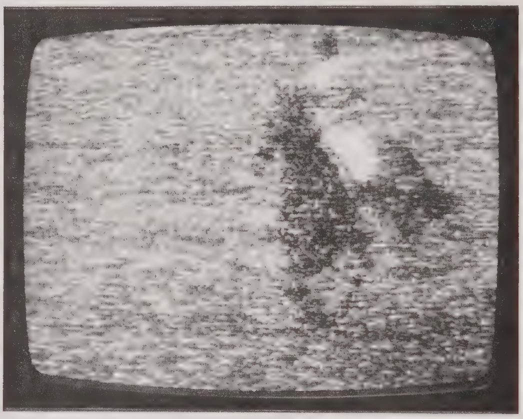


−15 dB

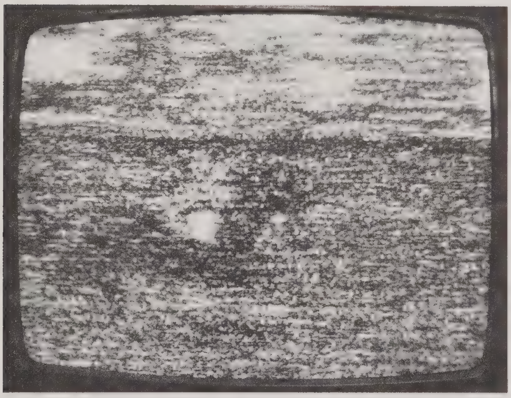
−10 dB



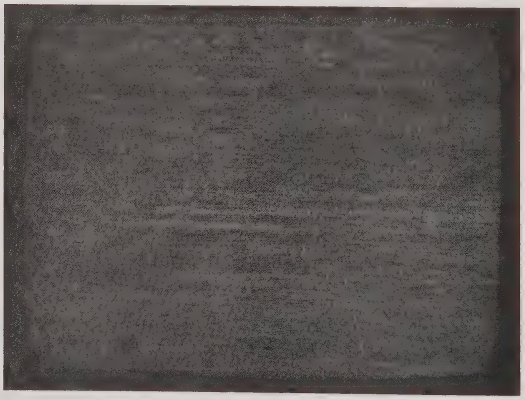
−5 dB ("sparklies")



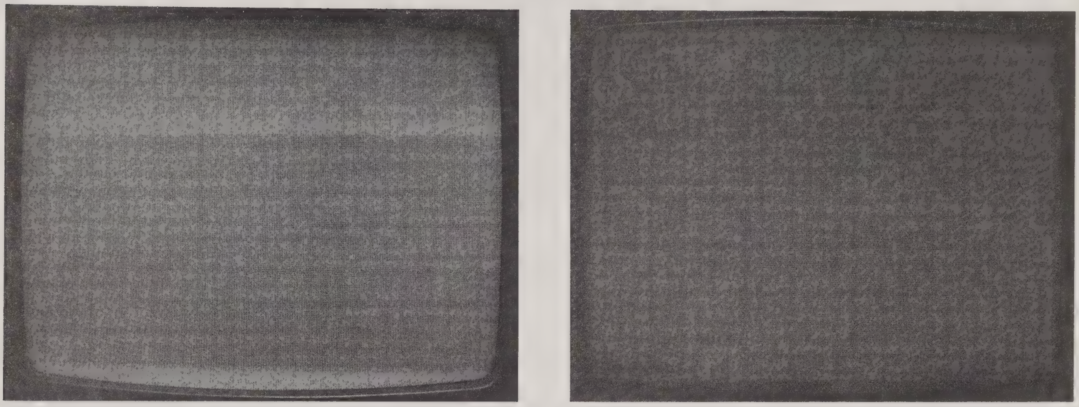
−3 dB ("flurries")



O dB ("blizzard")



+3 dB ("coarse screen")



+5 dB (blank, uneven screen)

+10 dB (blank screen with fine, uniform texture)

Figure 3-21. Effects of TI on Picture Quality. *As the interfering carrier power increases relative to the satellite signal picture quality deteriorates. The interfering carrier in all these cases is at −10 MHz relative to the satellite center frequency. (Courtesy of the Microwave Filter Company).*

Equipment Selection and Susceptibility to TI

The receiving antenna being the eyes of an earth station sees not only the targeted satellite but also noise and interference. Proper selection of the antenna/feedhorn/LNA assembly will avoid the need for later "band-aid" remedies to combat poor performance. In fact, a system with inadequate gain and poor noise rejection will often act as if it were detecting TI. And if TI is present, it will be much more susceptible to its effects.

The first step in avoiding TI is to choose a dish/LNA combination that can provide a C/N in excess of the receiver threshold. If a clear picture cannot be received under normal conditions without any interference, then if even light levels are present quality will be very poor.

A dish having a narrow beamwidth and low side lobes should be chosen. Interfering signals almost always come from directions off the main antenna axis and are detected by the side lobes. If the first side lobe is 30 dB rather than 20 dB below the main lobe, it will provide 10 dB more protection against TI. This may mean the difference between a watchable and a wiped out picture. Antennas having higher quality reflective surfaces will perform better since side lobes are substantially higher for dishes having rougher surfaces or slight warpage. One easy but perhaps costly solution for light to moderate levels of TI would therefore be to install a larger dish having a better surface accuracy. This selection will increase the main lobe and decrease side lobes. Another less costly strategy would be to use a deeper dish which generally has lower side lobes.

SELECTING EQUIPMENT

It is important to understand that TI is detected by side lobes and, very rarely, enters via the main lobe. This explains why TI might be seen when aiming at one satellite and may disappear when targeting an adjacent one. Moving the dish even a few degrees could cause the directional source of interference to fall between two side lobes and therefore be detected at much lower strengths.

For this reason, it is also clear why the feedhorn must be chosen to be compatible with the antenna f/D ratio. A feedhorn which over-illuminates a dish will cause an increase in detected side lobe power. On the other hand, one that under-illuminates will not take advantage of the possible antenna gain but will provide significantly lower side lobes.

The LNA should be chosen with an acceptably low noise temperature. Most LNA manufacturers have curves showing how rapidly gain falls off outside the 3.7 to 4.2 GHz band. Using a LNA with a good quality, built-in bandpass filter will afford protection against out-of-band interfering signals. Dealers should also realize that if an LNB or LNC is selected, it is impossible to place either a microwave bandpass or notch filter between the LNA and downconverter. The alternatives in the case of severe microwave interference are use of effective screening techniques or placement of a more expensive trap between the feedhorn and LNA.

A downconverter is susceptible to TI. A single conversion unit can also be a source of interference and should be mounted behind the dish. The oscillator mixing frequencies created for channel selection lie in the C-band range. If the downconverter were mounted directly onto the LNA, a

+5 dB TI at −10 MHz

+7.5 dB TI at −10 MHz

+10 dB TI at −10 MHz

Figure 3-22. Effects of TI and the AFC Circuit. *If the AFC circuit is manually disabled it no longer tracks interference and the receiver can be center- tuned on the satellite center frequency away from the TI. The earth station can then bear higher levels fo TI than otherwise. (Courtesy of the Microwave Filter Company).*

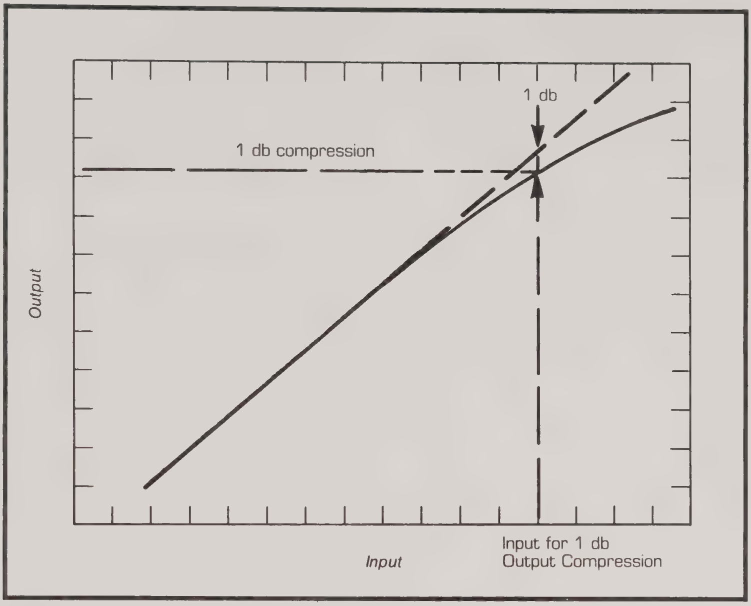


Figure 3-23. LNA Compression. *When signal levels entering the LNA are too strong the LNA is driven into compression, i.e. it enters a non-linear response region where the output is not directly related to input signal. This usually happens when strong interference is detected. The solution is to relocate the dish, use artifical screening techniques or to insert a filter between the feedhorn and LNA. (Courtesy of the Microwave Filter Company).*

slight leakage of signal could result in these oscillator frequencies being reradiated to the reflective surface only to be detected and reamplified as interference.

When selecting a receiver, it is useful to have an easily accesible AFC defeat switch. In cases of light to moderately heavy interference, defeating the AFC circuit and manually tuning away from the TI onto the center of a satellite signal can restore a picture. Similarly, a receiver with an adjustable bandwidth control can be a useful diagnostic tool during a site check or installation. If a reasonable picture can be restored by defeating the AFC or by narrowing the bandwidth, chances are good that a low-cost notch filter will overcome the problem.

Combatting In-Band TI

The method used to combat in-band TI depends upon the severity of the interference. For levels below -3 dB, notch filters, which remove a narrow band of signal centered on either 60 or 80 MHz, can restore nearly normal pictures. When using receivers having an IF different than 70 MHz such as the DX-700 which operates at 134 MHz IF, specially made notch filters operating at 124 and 144 MHz must be used.

In order to understand the operation of notch filters, remember that a satellite receiver lowers the frequency of each channel to a common

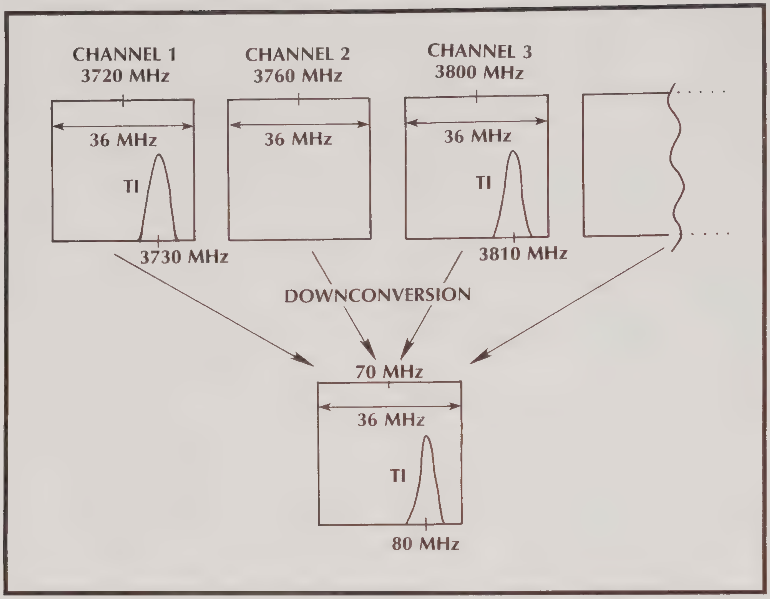


Figure 3-24. TI and Satellite Downconversion. *Both the common carrier transmissions and satellite signals are downconverted together on each channel to the final IF band of frequencies. The interference can lie 10 MHz above or below the satellite IF center frequency. This figures shows how TI carriers at 10 MHz above the satellite center frequency on both channels 1 and 3 are downconverted to the same 80 MHz location.*

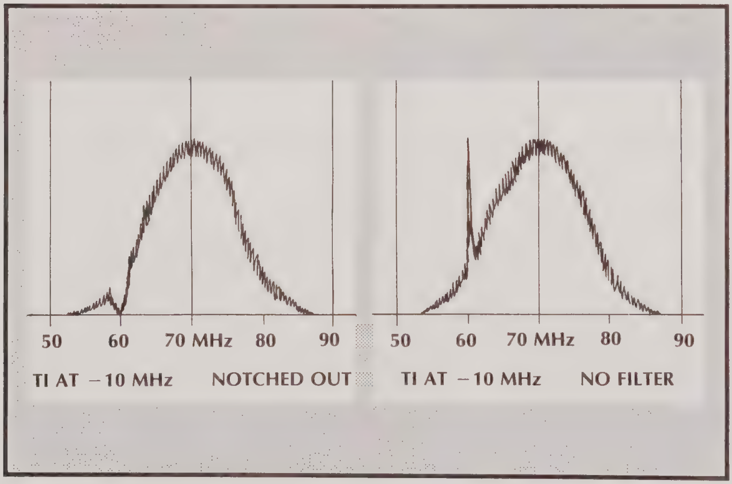


Figure 3-25. Notching Out TI. *These illustrations show how a satellite TV signal can carry interference at 60 MHz, 10 MHz below the center frequency, and how an IF filter can "notch out" the undesired signal. Actually, no real filter works perfectly but also removes some of the satellite signal wherever the notch is centered.*

band usually centered on 70 MHz. Since the TI is located 10 MHz either above or below the satellite center frequency, every earth-based transmission is also translated to either 60 or 80 MHz. Combatting in-band TI with notch filters is simple because one filter can eliminate interference on all channels.

As the TI level begins to exceed -3 dB, microwave filters or traps must be used. One trap is required for each interfering frequency. At levels above +10 dB a special type of microwave filter, a three resonator trap, is required. The complexity and cost of finding a technical solution for TI increases futher as TI power grows stronger. At levels above +35 dB, very costly, specially-made traps must be placed between the feedhorn and LNA to allow the LNA to function. Note that when an LNB or LNC is used traps cannot be placed between the low noise amplifier and the internal downconverter. So if TI is severe, an LNB system may have to be replaced with an LNA and more conventional single or dual downconversion receiver. Another alternative is to not attempt to do the installation.

Filtering wide band interference is not possible with conventional notch filters which remove narrow bands of signal and interference. If the TI covers the full satellite broadcast bandwidth, then notching out the TI also removes the television signal. The solution to this problem other than moving the antenna or using artifical screens is called phase cancellation. This method is simple on paper. A sample of the TI which is taken with a second feedhorn and amplifier is subtracted from the satellite signal plus TI by shifting its phase 180 degrees and adding the signals together. This leaves just the satellite signal and eliminates the TI. Unfortunately, this method requires costly, sensitive equipment and is not one used by the average dealer on the average installation.

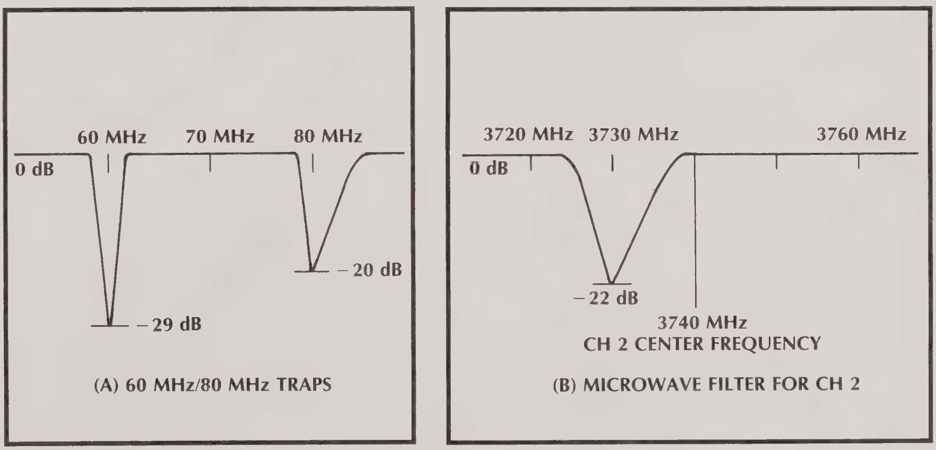


Figure 3-26. The Effect of a Notch Filter. *If TI is present a notch filter can selectively cancel it out. Diagram A shows the effects of a 60 MHz and 80 MHz filter in series. In this case, any signal centered on 60 MHz would be attenuated by 29 dB. Diagram B shows the response of a typical microwave filter designed to suppress interference at 10 MHz below the satellite signal center frequency. It notches out a wider band than a IF filter.*

Selection of RF and Microwave Filters

How does a dealer who encounters TI decide on the brand and type of filter to purchase from the myriad available? First, any potential problem must be diagnosed correctly starting with the site check. If possible, as is often the case, TI can be avoided. When filters are needed, the type required depends upon the source and power level of the interference.

Filters can be grouped into two basic categories: notch filters, or traps; and bandpass filters. "Threshold extension" filters are a subclass of bandpass filters designed for use in the IF range. Most of these can be constructed in active or passive designs.

Passive filters are inexpensive and uncomplicated. They are constructed from standard electrical circuit elements and do not need to be "plugged in." Since these use no power, they provide no gain as the signal passes through. In fact, they have an "insertion loss," ranging from nearly zero to substantial decreases in signal power depending upon the type used.

Active devices need power to function and usually have an integrated circuit and either a ceramic filter or a surface acoustic wave (SAW) filter to limit the range of rejected frequencies. They can be smaller than passive units and amplify as well as filter the processsed signal. Disadvantages include their need for external power and higher cost.

All notch filters are rated by the amount that the TI is reduced. This corresponds to the depth of the notch. For example, a filter which was rated for -40 dB would reduce an 8 dB interfering signal to -34 dB.

Just a short few years ago about the only company catering to the home satellite market was Microwave Filter Company which manufacturers a wide range of filters. Others such as Alaun Engineering, Arunta, R.L. Drake, Earth Station Products, and Phantom Engineering now offer conventional IF notch and threshold extension filters.

Notch filters, designed for use in the IF range, eliminate a portion of the frequency spectrum during the process of wiping out interfering carriers. The notches, which are centered on or close to either 60 or 80 MHz, are characterized by the relative suppression of power in this notch and by the width or range of frequencies affected. Obviously, if a Ma-Bell carrier centered on 60 MHz and having a width of 3 MHz is attacked, the ideal filter would eliminate only this band of frequencies. Any more would cause undue loss of the wanted satellite signal.

Figure 3-27. Passive Notch Filters. *The Microwave Filter Company model numbers 4518-60 and 80F notch filters can be used separately or in series to reduce interfering carriers centered on a final IF of 70 MHz. (Courtesy of the Microwave Filter Company).*

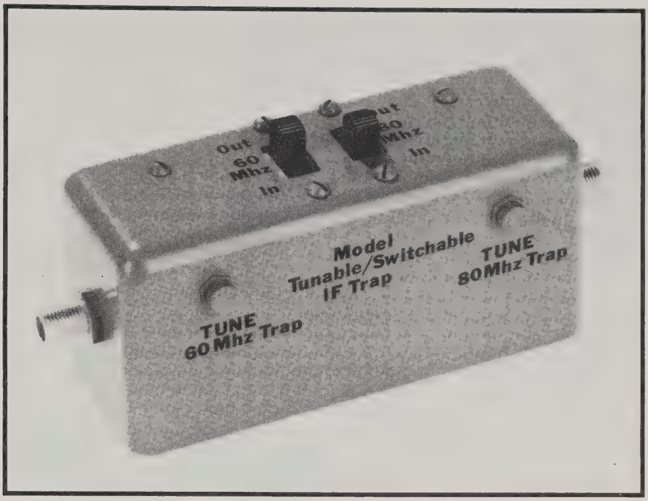


Figure 3-28. Switchable Notch Filters. *MFC model 4616 dual 60 /80 notch filters can be switched into and out from the circuit without being disconnected. Their notch depth is more than 20 dB and their 3 dB bandwidth is 4 MHz. The center frequency of each trap can be independently tuned to adjust for slight downconversion frequency error. (Courtesy of the Microwave Filter Company).*

Some notch filters are equipped with adjustments on one or all of depth, width and center frequency. Some can also be switched in and out of action so that when not required they do not degrade picture quality by unnecessarily removing a portion of the spectrum. For example, MFC's 3217LS-60 and 80 passive notch filters can be used separately or in series to reduce interfering carriers by about 53 dB. They can be field-tuned by two screwdriver adjustments. These filters, like most other notch filters avaiable, can easily be inserted in the IF line to the receiver by using an F-connector input and output. MFC model 4616 dual 60/80 notch filter is also field tuneable, reduces carriers by about 29 dB and can be switched into and out from action without being disconnected.

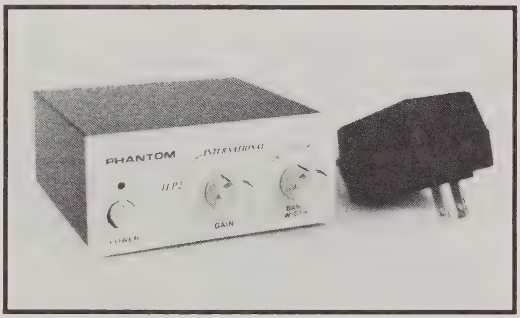


Figure 3-29. Adjustable Notch Filter. *The Phantom Engineering IFP1x adjustable notch filter has an adjustable bandwidth ranging from 18 to 32 MHz. Like all other 70 MHz notch filters it can only be used with block downconversion receivers providing access to the 70 MHz internal line. Note that the setting of 26 MHz will have no effect if the receiver's internal IF bandwidth is 24 MHz. (Courtesy of Phantom Engineering, Inc.).*

Threshold extension filters are similar to those used by some manufacturers to lower the apparent receiver threshold. They restrict the bandwidth of the signal entering a receiver and eliminate noise, some satellite signal and hope-

Figure 3-30. 134 MHz Notch Filters. *These two brands of notch filters are designed for use with receivers such as a DX-700 which operates at a final IF of 134 MHz. (Courtesy of Phantom Engineering, Inc. and Conifer Antennas, Inc.).*

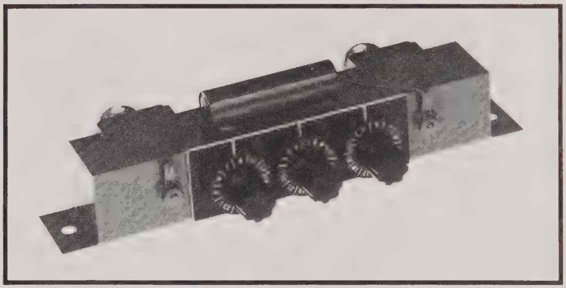


Figure 3-31. Tunable Microwave Bandpass Filter. *This bandpass filter can be tuned to any particular transponder frequency in the C-band. It has a 3 dB bandwidth of 40 MHz with under 1.5 dB insertion loss. If several are to be used in series, a 50 dB LNA should be used. (Courtesy of the Microwave Filter Company).*

fully, in the process, the interfering carrier. For example, the E.S.P. PFG-20 and 50 active devices use a SAW to produce a steep-skirted frequency response and add about 4 dB of additional gain. E.S.P.'s PGF-50 provides about 53 dB carrier power reduction and a -3 dB bandwidth of only 13 MHz.

Some notch filters can have similar effects to receivers which reduce threshold by narrowing bandwidth. If the width of two filters located at 60 and 80 MHz is increased, the band between them becomes squeezed down. For example, if the bandwidth of each trap were 4 MHz then the middle bandpass region would range from 64 to 76 MHz, a bandwidth of only 12 MHz.

Bandpass filters are designed to allow only a selected band of frequencies into the downstream electronics. For example, MFC's 4352 bandpass filter passes only 3.7 to 4.2 GHz. It directly connects into the line between the LNA and downconverter with male/female N connectors so no jumpers are necessary. The 3966A can be adjusted to pass only one of any selected transponder frequency in the C-band.

Figure 3-32. Microwave Bandpass Filters. *The MFC 4352 bandpass filter is designed to pass only those frequencies in the 3.7 to 4.2 MHz range. It directly connects into the 4 GHz line between the LNA and downconverter so that no extra cable or connectors are necessary. This filter also passes DC power. (Courtesy of the Microwave Filter Company).*

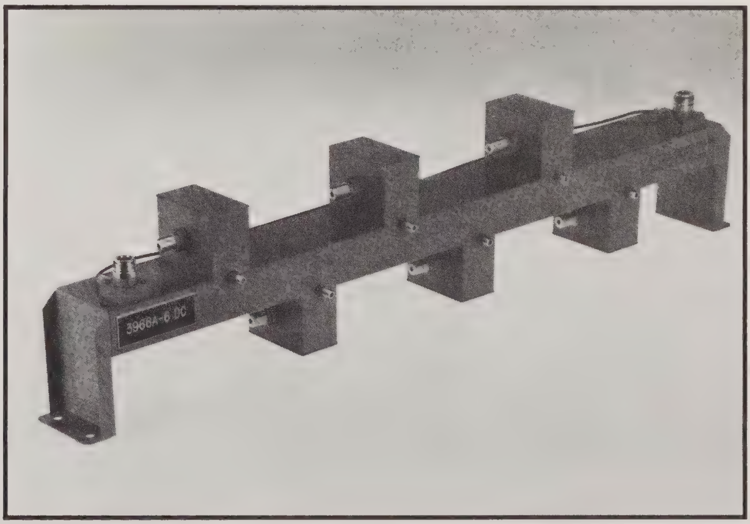


Figure 3-33. Adjustable Microwave Notch Filter. *The MFC 3966A-6 is installed between the LNA and downconverter to notch out up to 6 telephone carriers. Each notch, which should be aligned with a spectrum analyser, can be tuned to any 4 GHz carrier. (Courtesy of the Microwave Filter Company).*

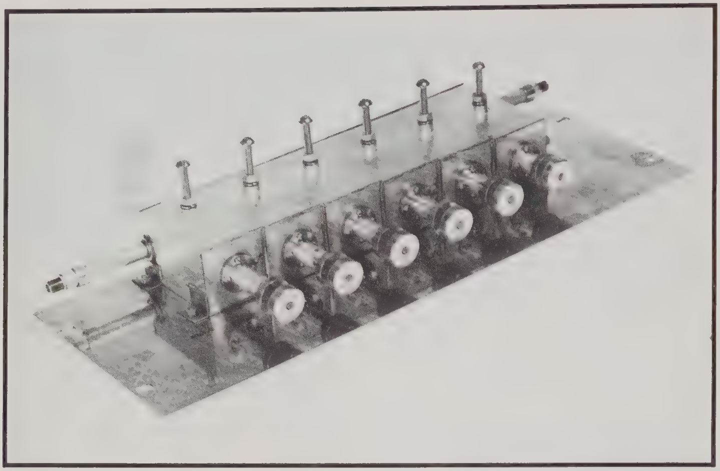


Figure 3-34. Block Downconversion Microwave Trap. *This filter notches out 6 frequencies in the 950 to 1450 MHz band. Each notch can be adjusted in depth to approximately 15 dB and the center frequency can be tuned over six 80 MHz adjacent bands to cover the entire 500 MHz bandwidth. (Courtesy of the Microwave Filter Company).*

D. BEAMWIDTH AND SATELLITE SPACING

There is no mistaking the fact that smaller antennas are more appealing to all except the rare individual who thinks bigger always means better. As satellite power levels have risen from 5 to 9 watts and even higher and as earth station technology improves, ever small antennas can produce excellent quality video. Five years ago an antenna less than 10 to 12 feet in diameter was considered unthinkable. Today even 4 foot dishes are being marketed.

The question of satellite spacing confuses the move towards smaller antennas. Dealers must consider whether or not a six or seven foot dish that works just fine today will have unacceptable performance when and if satellites are spaced more closely together at 2° intervals.

The issue of satellite spacing was not seriously considered until 1980. RCA Americom had been operating two satellites, Satcom I and II, Western Union had three vehicles, Westar I, II and III, and AT&T/GTE operated Comstar I, II and III. There was more than ample orbital space. In 1981, the FCC suprised the industry by requesting comment on the possibility of authorizing spacing of satellites along the North and South American portion of the geosynchronous arc at 2° intervals. Until then, the accepted policy was 4° and 2° spacing for C and Ku-band satellites, respectively.

In April, 1983 the FCC approved 2° orbital spacing for satellites operating in both frequency bands. This decision, to be im-

plemented gradually by reducing spacing to 3° at first, will eventually allow a doubling of the orbital arc capacity.

What size dish will be needed if this policy is implemented? It is important that consumers be protected and that dealers maintain a credible reputation by selling equipment that will work not only today but also tomorrow.

The Importance of Beamwidth

Antenna quality and beamwidth are critical factors. For example, if the half power (3 dB) beamwidth of a dish is 4°, then at half of this value or 2° on either side of the main axis, signals are received at 3 decibels lower than those detected along the boresight. If a satellite happens to be located just 2° off the target and is transmitting on the same channel and polarity, two garbled pictures and the resulting interference will appear on the screen.

What if the antenna detected signals at two degrees off boresight at powers reduced by 10 decibels, or 15 decibels? At what level is a picture judged unwatchable or is interference from an adjacent satellite just barely detectable. M. Gustafson conducted a series of tests which showed a interfering signal was first noticeable when its level was 11 decibels below the wanted signal. It was almost objectionable when received at -5 decibels and objectionable at -4 decibels. He calculated and measured the following:

TABLE 3-7. ANTENNA SIZE VERSUS 10 DECIBEL BEAMWIDTH

Antenna Diameter (feet)	Half Beamwidth Calculated	Half Beamwidth Measured
6	2.8	2.7
8	2.1	2.1
9	1.9	2.1
10	1.7	2.3

This means that a six foot antenna will see interfering signals reduced by only 10 dB at 2.8° off the main axis. Levels will even be higher at 2°. However, a good quality 10 foot dish will have unwanted signals reduced by substantially more than 10 dB at 2° off axis. The 10 foot antenna used for performance testing here was certainly not up to calculated specs. Obviously, antenna quality plays an important role.

Note that most prime focus parabolic antennas have adequately low side lobes so that off-axis signals are not appreciably detected. However, smaller Cassegrain type dishes can have side lobes only 10 decibels lower in power than the main lobe. Such antennas are more susceptible to interference from adjacent satellites as well as from terrestrial sources.

The Role of Antenna Quality

An antenna with an accurate surface and a well-matched and placed feed assembly will be closer to optimal performance and have a smaller beamwidth than a poorer quality dish. This is because calculated beamwidths are also determined by antenna efficiency.

For example, a 8 foot antenna with a 55% efficiency will have 4.2 degree 3 dB beamwidth. The same sized dish with a 70% efficiency will have a much lower 3.7° beamwidth. This means that an excellently made 6 foot dish will have power reduced by 3 decibels relative to the main lobe at only 1.85° off axis. At 2° the power received could be down by perhaps as much as 10 decibels. Note that smaller antennas are made with much less materials, so leftover manufacturing dollars could be spent in realizing better surface accuracy. And better accuracy can be achieved with more manageable smaller dishes.

Is 2° Spacing Really 2°?

The published separation between satellites is measured by their differences in longitutude. From the perspective of an observer at the center of the earth, the angular separation between two satellites directly overhead would be the same as their longitutude difference. But a dish located on the surface pointing straight upwards would see these satellites separated by more than two degrees. This spacing decreases as satellites closer to the horizon were targeted but still remains in excess of 2 degrees.

When an earth station antenna is located at other points on the surface of the earth, the perceived separation between satellites will also have values in excess of 2 degreees. For example, from Honolulu, Hawaii satellites at 131° and 133° longitutude will appear to be not 2° but 2.27° apart. Note that these angles are simply related to the geometry of the situation.

This is good news. Two degree spacing does not mean that the power levels at 2° on a beamwidth diagram tell the whole story. In the above example, an antenna may have only a 8 decibel drop in power detected from a satellite at 2° off boresight but an acceptable 12 decibels at 2.27°. Interference which would have been detected at -8 decibels would not be noticeable at -12 decibels.

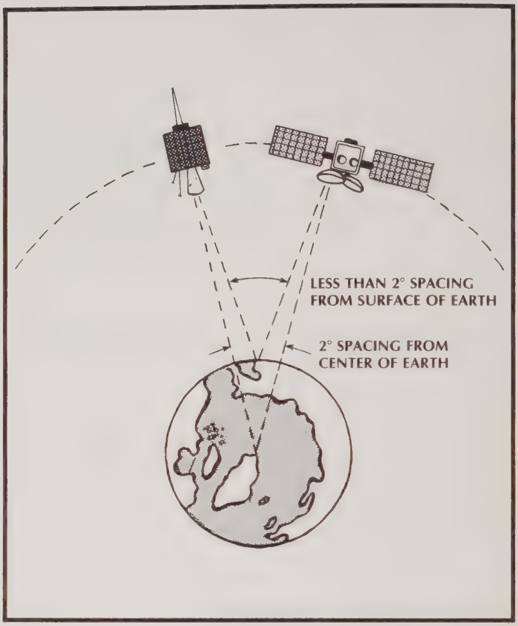


Figure 3-35. Why 2° Spacing Can Vary. *Satellites spaced 2 degrees apart are really separated by a slightly larger angle. This is because the reference angle is measured from the center of the earth but an antenna sits closer to the arc of satellites.*

Satellite Spacing and the FCC

In all probabality, smaller dishes will be perfectly adequately even when satellites are spaced at 2° intervals if polarization formats alternate between satellites. Thus, if an earth station was tuned to channel 5 having vertical polarization, and an adjacent satellite was transmitting the same channel on horizontal polarization, the feedhorn would hardly detect these interfering signals of opposite polarity. This "cross-polarization discrimination" adds approximately 20 decibels of additional protection from interference. For example, even if a five foot dish saw adjacent satellite signals at only 6 decibels below the desired transmission,

the added protection incurred by using cross polarized signals would knock these interfering levels down to a perfectly manageable 26 decibels.

Note that using a small dish still has potential problems. The gain may not be sufficient to detect the weaker transponders without unwanted sparklies. And a dish having a wide main lobe and high side lobes is much more susceptible to terrestrial interference. The chosen antenna size will depend upon whether or not TI might be a problem, dish quality and what type of reception is judged adequate.

E. MULTISTANDARD TELEVISIONS

Television broadcasts are relayed in four principle formats throughout the world: NTSC, PAL, SECAM vertical and SECAM horizontal. A television set, monitor or VCR designed for one system will not receive any of the others. As the satellite television business grows, more and more dealers are beginning to branch out into installing systems in countries around the world. It is important to be familar with which countries have have adapted which formats. The technical characteristics underlying these formats are listed below in Table 3-8.

TABLE 3-8. Broadcast System Characteristics

System	Number of Lines	Channel Width	Video Bandwidth	Video/Audio Separation	Audio Modulation
A	625	7	5	5.5	FM
B	625	8	6	6.5	FM
C	625	8	5	5.5	FM
D	625	8	5.5	6.0	FM
E	625	8	6	6.5	FM
F	625	8	6	6.5	AM
G	525	6	4.2	4.5	FM
H	625	6	4.2	4.5	FM

Broadcasts engineers have drawn upon these technical parameters and combined them with either the NTSC, PAL, SECAM vertical or SECAM horizontal formats. Table 3-9 below lists the various system designs used in a sample of countries around the world.

TABLE 3-9. Worldwide Adapted Television Formats.

Argentina	PAL G,H	Ireland	PAL D
Australia	PAL A,C	Israel	PAL A,C
Bahrain	PAL A,C	Italy	PAL A,C
Barbados	NTSC G,H	Japan	NTSC G,H
Belgium	PAL A,C	Jordan	PAL A,C
Bermuda	NTSC G,H	Kuwait	PAL A,C
Bolivia	NTSC G,H	Luxembourg	SECAM-V F
Brazil	PAL G,H	Mexico	NTSC G,H
Canada	NTSC G,H	Netherlands	PAL A,C
Chile	NTSC G,H	New Zealand	PAL A,C
China	B,E	Nicaragua	NTSC G,H
Cuba	NTSC G,H	Norway	PAL A,C
Czechoslovakia	SECAM-V B,E	Panama	NTSC G,H
Denmark	PAL A,C	Peru	NTSC G,H
Dominican Republic	NTSC G,H	Portugal	A,C
Ecuador	NTSC G,H	Puerto Rico	NTSC G,H
Egypt	SECAM-V A,C	Saudi Arabia	SECAM-H A,C
El Salvador	NTSC G,H	Spain	PAL A,C
Finland	PAL A,C	Sri Lanka	PAL A,C
France	SECAM-V F	Sweden	PAL A,C
German Demo. Rep.	SECAM-V A,C	Switzerland	PAL A,C
German Fed. Rep.	PAL A,C	Tahiti	SECAM-V B,E
Greenland	NTSC G,H	Taiwan	NTSC G,H
Guam	NTSC G,H	United Kingdom	PAL D
Guatemala	NTSC G,H	United States	NTSC G,H
Haiti	SECAM-V G,H	U.S.S.R.	SECAM-V B,E
Hong Kong	PAL D	Venezuela	NTSC G,H
Iceland	PAL A,C		

Recently video components equipped to process any of these formats have been introduced onto the market. A single microchip acts as the translator by "reading each language," translating to a common one and then retranslating to the chosen format. These multistandard televisions, monitors and VCRs can therefore be used anywhere worldwide.

FIGURE 3-10. MULTISTANDARD TELEVISIONS

Black and White

Model	Screen Size (inches)	Systems
Panasonic TR 1215X	12	NTSC/PAL
Sanyo TPM 2170	2	NTSC/PAL

Color

Model	Screen Size (inches)	Systems
Hitachi CMT-2080	20	NTSC/PAL/SECAM
Hitachi CMT-2083	20	NTSC/PAL/SECAM
Hitachi CMT-2683	26	NTSC/PAL/SECAM
JVC AV-20ME	20	NTSC/PAL/SECAM
JVC 7255 ME	14	NTSC/PAL/SECAM
JVC 7755 ME	20	NTSC/PAL/SECAM
Panasonic TC 4000 E	40	NTSC/PAL/SECAM
Panasonic TC 26 NPR	26	NTSC/PAL
Panasonic TC 224 NPR	20	PTSC/PAL
Panasonic TR 1215 X	12	PTSC/PAL
Philips 20 CT-3130	20	NTSC/PAL/SECAM
Philips 20 CT-3430	20	NTSC/PAL/SECAM
Philips 26 CT-9430	26	NTSC/PAL/SECAM
Sanyo CTP3467N	14	NTSC/PAL/SECAM
Sanyo CXM7065	22	NTSC/PAL/SECAM
Sanyo CXM6065R	20	NTSC/PAL/SECAM
Sanyo CXM6055RH	20	NTSC/PAL/SECAM
Sanyo CTP64671	20	NTSC/PAL/SECAM
Sanyo CTP64681	20	NTSC/PAL/SECAM
Sharp C2002P	20	NTSC/PAL/SECAM
Sharp DV1400SPN	14	NTSC/PAL/SECAM
Sharp DV1600SPN	16	NTSC/PAL/SECAM
Sharp DV2100SPN	20	NTSC/PAL/SECAM
Sharp C262SPN	26	NTSC/PAL/SECAM
Sharp DV262SPN	26	NTSC/PAL/SECAM
Sony KV-2062AEB	20	NTSC/PAL
Sony KV-2024AEB	20	NTSC/PAL
Sony KX-20 PSE	20	NTSC/PAL/SECAM
Toshiba C2647QBP	26	NTSC/PAL/SECAM
Toshiba C2057QBP	19	NTSC/PAL/SECAM

F. SCRAMBLING

The word scrambling conjures up different visions for different people. Some dealers see it as the death knell of home satellite TV. Others see it as an opportunity to sell more equipment. Many consumers now understand that there is already so much video relayed by satellite that if a few channels are lost the difference will be small. Many cable companies and other mass retailers are becoming aware of the opportunity that home satellite TV presents to open new, untapped markets and to increase their profits.

It is clear that program producers must be paid for their efforts because it is very expensive to produce even an hour of quality programming. As would be expected, the consumer will certainly end up footing the bill in one way or another. And generally their decisions are made on the basis of cost comparisons. For example, if the monthly costs of cable are $40 for 20 channels and those for satellite TV are $50 for 120 channels, satellite TV will be often be chosen when their is room for a dish and when it is considered an attractive addition. In those cases where TV reception is desired and where no other alternatives exist, as is the case in maybe one million households in the United States, substantially higher costs may be incurred. The cost to purchase decoders and monthly fees will simply be figured into the totals. And as satellite equipment becomes less expensive and as more effective financing programs are adopted, these totals will look even more attractive.

Satellite broadcasting certainly has a role as a key program distribution method for many years to come. In particular, home satellite TV has an enormous market in areas unserved by cable and off-air TV. The methods to pay program suppliers will often involve scrambled signals but such technologies have taken years to create and will probably still be under development for years to come.

In order for the program suppliers to have good control over who decodes their signals, scrambling systems must be capable of "addressing" the descramblers in the field. This means that each end-user such as a cable TV headend or a home satellite system would have a decoder which could be turned on or off from the central uplink. While it is a relatively easy matter to build non-addressable devices, addressable systems require a high level of sophistication. These must be perfected before they find widespread use. Interesting problems can arise. For example, what if the address of one cable TV headend is partially garbled and that company suddenly is not capable of decoding a broadcast. It may have thousands of paying subscribers who will not receive one or more premium channels. While the talk of implementing scrambling is thick, in reality, scrambling is being carefully and slowly introduced.

Four companies are presently developing scrambling systems. MACOM, Oak Industries, Scientific Atlanta (Plessey) and General Instruments have systems called Link-A-Bit, Orion, BMAC and Starlock, respectively. Discussing their technical details is not appropriate at this point since systems are still under development. However, the home satellite dealers should be aware that decoders may need an especially high C/N input to the satellite receiver and decoder for it to function well. This is because, in some systems, the audio information is relayed in a digital form in the vertical blanking interval, that space of time between scanning successive frames of video. Therefore, a C/N of at least 11 dB may be needed to properly decipher this hard to read audio message. In other words, an undersized dish might not be capable of providing enough signal power to actually drive a decoder, so systems should be designed with an adequate margin of performance.

G. HIGHER FREQUENCY BROADCASTS

The move towards higher frequency satellite communications has occured for a number of reasons. This technical frontier offers a large amount of available frequency spectrum which can potentially lower communication and broadcasting costs. C- and Ku-band signals do not interfere with each other at all so one satellite can relay both types of messages. Since microwave antennas are more efficient at higher frequencies, satellites can transmit higher power signals and smaller 2 or 3 foot dishes can be used for excellent reception of Ku-band transmissions.

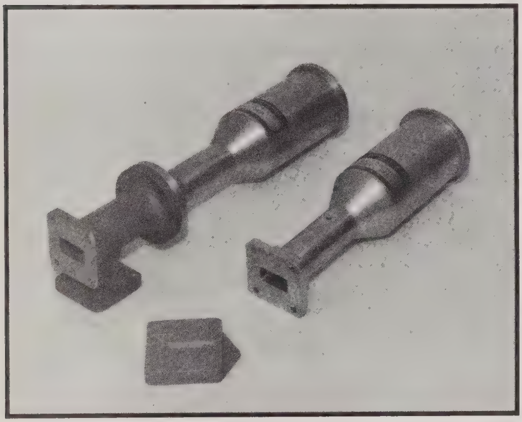


Figure 3-36. Ku-band Feeds. *These feeds are designed for use with 1.2 meter (4 foot) and 1.8 meter (6 foot) antennas operating in the Ku-band of frequencies. The feedhorn on the left is capable of simultaneously receiving both vertically and horizontally polarized signals. (Courtesy of Seavey Engineering Associates, Inc.).*

The large majority of C-band antennas can be retrofitted for receiving Ku-band broadcasts. Either a dual-purpose feedhorn designed to receive both frequency ranges must be used (see Figure 2-32) or the feedhorn must be replaced with one just for Ku-band reception. If the downconverter IF output is the same for both Ku- and C-band broadcasts, then one receiver may be used to detect either transmission. For example, this is possible if both the 3.7 to 4.2 GHz and 11.7 to 12.2 GHz ranges are downconverted to 950 to 1450 MHz. Another reasonable option to receive both broadcast formats is to install a second much smaller Ku-band antenna equipped to downconvert to the same frequency range as the parallel C-band system. An A/B switch would be used to choose either format for input to one receiver. Note that all multi-band receivers cannot be used for all Ku-band broadcasts because some have bandwidths as wide as 72 MHz, eg. Spacenet I.

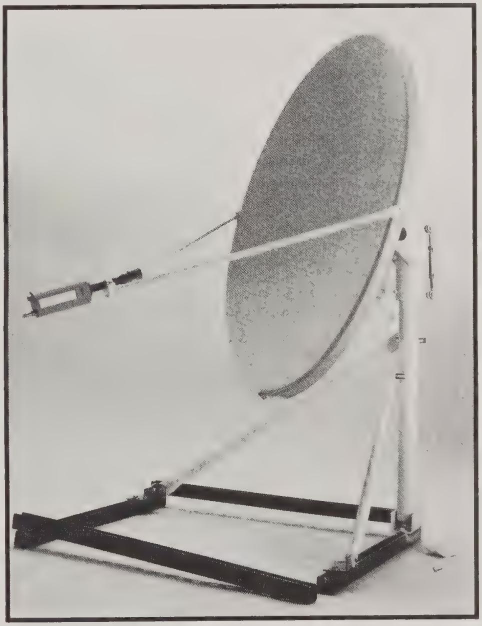


Figure 3-37. Ku-band Antenna with Offset Feed. *Antenna gain is higher and beamwidth is more narrow at higher frequencies. Since satellite powers are also higher, much smaller dishes can be used in the Ku- band. The Lowrance 1.2 meter (4 feet) antenna has an offset feed to minimize side lobes and maximize efficiency. (Courtesy of Lowrance Electronics).*

Usually the same antenna used for C-band reception will work with higher frequency broadcasts. Although a Ku-band dish requires a much more accurate reflective surface for efficient reception, the EIRP is so much higher that even an inefficient, C-band dish will manage fine. For example, a typical 10 foot antenna has over ten times the surface areas of a comparable 3-footer which could be used for Ku-band reception. Having so much extra reflector surface area can be technically very forgiving. Note that some wire mesh dishes will have trouble reflecting higher frequency microwaves. Holes in the mesh should be less than one tenth of the microwave wavelength (one tenth of an inch since the wavelength at 12 GHz is approximately 1 inch) so that signals will not just pass through without being reflected. Dishes with much larger openings will simply allow some of the microwave energy to pass right through the dish.

Antennas must be pointed with greater accuracy to properly track Ku-band than C-band broadcasts. This is because the beamwidth of any antenna decreases as microwave frequency increases. Therefore, Ku-band broadcasts, which have 3 times the frequency, are relayed with one third the beamwidth from the same size antenna compared to C-band transmissions. This need for tracking accuracy is similar to that encountered when doing installations in out-of-footprint locations with very large antennas having narrow beamwidths (see Chapter VI).

The frequency and polarization formats used by Ku-band satellites are not standardized like they are for C-band relays. Channel bandwidths as well as the center frequencies vary between satellites and occasionally even circular polarization is used. Table 3-11 shows the formats used by some of these Ku-band vehicles.

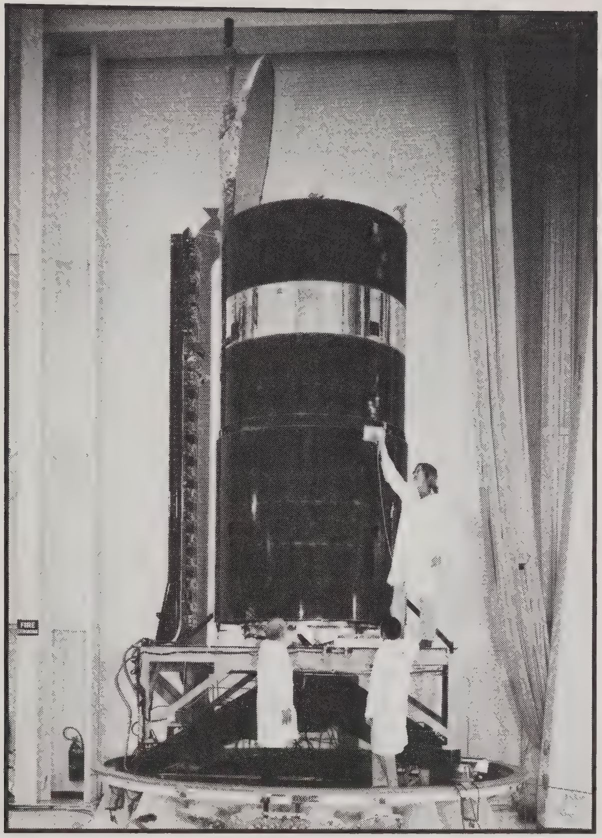


Figure 3-38. SBS-1 Satellite. *This Ku-band satellite, first of a series of four, transmits voice, data and video information. It has two concentric cylindrical solar panels which telescope in space from 9 feet to nearly 22 feet. (Courtesy of Hughes Aircraft Company).*

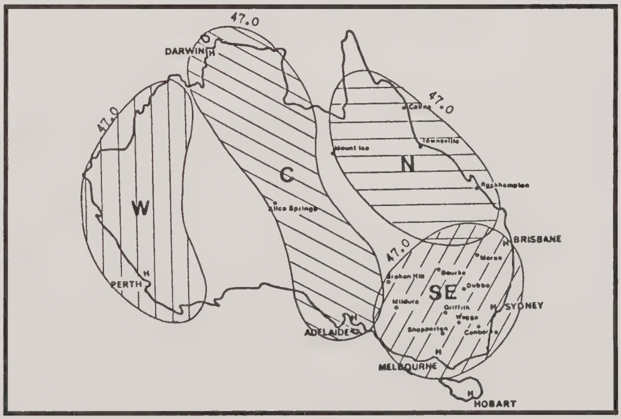


Figure 3-39. Ku-band Satellite Footprints. *The planned Aussat satellite has four spot beams from 30 watt transponders covering the populated areas of Australia. The EIRP, expressed in dBw, is much higher than that from a C-band satellite.*

TABLE 3-11. KU-BAND SATELLITE BROADCAST FORMATS

Satellite(s)	Orbital Location (°W)	Transponder Power (watts)	Channel Bandwidth (MHz)	Center Frequencies MHZ Horizontal	Center Frequencies MHZ Vertical
SBS 1-4	99	20	43	11.275	
	97			11.774	
	95			11.823	
	101			11.921	
				11.970	
				12.019	
				12.068	
				12.117	
				12.166	
Spacenet 1-2	120	16	72	11.740	
	69			11.820	
				11.900	
				11.980	
				12.060	
				12.140	
Anik C1-3		15	54	11.730	11.743
				11.791	11.804
	117.5			11.852	11.865
				11.913	11.926
	(Horizontal - East Spot Beam)			11.974	11.987
	(Vertical - West Spot Beam)			12.035	12.048
				12.096	12.109
				12.157	12.170
GStar 1-2	103	20 & 30	54	11.730	11.744
	105			11.791	11.805
				11.852	11.866
				11.913	11.927
				11.974	11.988
				12.035	12.049
				12.096	12.110
				12.157	12.171
Morelos 1-2	113.5	20	108	11.764	
	116.5			11.888	
				12.012	
				12.136	

IV. HOW TO CORRECTLY INSTALL A SATELLITE TV SYSTEM

The point of this manual is to teach how to correctly install satellite receiving systems which will stand the test of time. All your knowledge about theory and equipment selection is worth only the paper it is written upon unless the result is a properly functioning system. And all your troubleshooting expertise will be overtaxed if the installation has serious flaws.

We examine each installation step in detail and try to leave no stone unturned. Please note that for simplicity some of these steps are presented in a slightly different order than would occur during an average installation. For example, wiring actuators is outlined in section E with the rest of the information on actuators before the description of mounting and connecting the downconverter. Some dealers will prefer to attach the downconverter before doing any wiring. Also, for example, the section on aligning the feed preceeds a description of mounting actuator arms. Dishes using linear actuators can be held securely in place by installing the arm before the feed assembly.

But the exact order of each step is often a matter of personal taste. Every dealer will certainly develop a slightly different strategy and method in following these instructions. We are always grateful to those who show us a better way to accomplish the same results.

A. THE SITE SURVEY

A well conducted site survey is the first and one of the most critical steps in a satellite TV installation. It is often underrated. This first task is the equivalent of a doctor's check-up and diagnosis prior to surgury. A smart surgeon would never open up a patient without a thorough understanding of where his scapel will take him. A competent dealer will not cut corners in conducting a site survey.

Three important tasks are completed during a site survey. First, a location with a clear view of the entire arc of satellites must be found. Second, a test is conducted to determine whether or not terrestrial interference is present at this location. Third, the entire installation is planned.

TABLE 4-1. THE SITE SURVEY	
FIRST -	Ensure a Clear View of the Arc
SECOND -	Test for Interference
THIRD -	Plan the Entire Installation

Important facts such as what type of equipment will be used, where to place the dish, how much concrete is necessary, whether or not to use a long pole or ground mount and what length and type of cable is required must be determined in advance of installation. Always remember to keep the customer's wishes in mind since all these steps must be cleared with the final decision maker. For example, if the customer does not want the dish next to her home but 100 yards away, RG-6 cable and 12 gauge actuator wire will have to be used instead of RG-59 coax and 14 gauge wire. And mark these cable paths clearly since another member of your company might be the one who actually installs this system.

Treat the customer's home and yard as if it were personal property. Respect the saying that "the customer is always right".

Ensuring a Clear View of the Arc

A dish must have a clear, unobstructed view of each satellite. All obstructions located between the dish and targeted satellite will absorb or reflect microwaves and make pictures unwatchable. Water is a particularly strong absorber of microwaves. There have been cases where a dish installed in the winter had perfect reception until foliage returned in the spring to

Figure 4-1. Ensuring an Unobstructed View of the Arc. *Any trees, buildings or other obstructions blocking a clear shot to any satellite will make receiving a broadcast difficult, if not impossible. The first objective of a site survey is to guarantee a clear view of all or most of the geosynchronous satellites.*

those trees obstructing its view. Then pictures either disappeared or were very poor quality.

Two instruments are required to locate the satellites: an inclinometer and a compass. Each satellite can be targeted by knowing its azimuth and elevation angle. This azimuth is measured by degrees of rotation from true north and the elevation by degrees up from the horizon.

Finding True South

A compass will point towards magnetic north. In most locations the directions to magnetic north and true north, the actual position of the north pole, will differ. This is because magnetic north, the strongest magnetic center near the north pole, is located near Bathurst Island off the northern coast of Canada. This magnetic variation can exceed 30 degrees in northerly locations such as Alaska. Magnetic variation is zero along the "agonic line" that runs just off the west coast of Florida, through Lake Michigan and to the magnetic north pole. East of this line, the north pole is east of the compass reading, west of this line it is west (see Figures 4-6, 7 and 8).

True south can therefore be found by using a compass and correcting for this magnetic variation. For example, in Denver, Colorado, magnetic variation is -12.5 degrees. So the arc of satellites which is centered on true south is found by rotating 12.5 degrees east of the south reading on a compass. This is equivalent to a compass reading of a 167.5 degrees (180 less 12.5 degrees) as measured from true north.

Magnetic variation in any location can be found from the chart shown here or by requesting the value from your local airport information service. Airplane pilots like satellite TV installers must also take their bearings from true north and south.

Note that a compass can give inaccurate readings when used in the vicinity of ferrous objects. So a reading taken next to a large truck or other large steel objects could be many degrees off magnetic north. Stand well back from an iron mount when reading a compass.

Determining the Azimuth and Elevation Look Angles

The azimuth heading towards any chosen satellite is found by looking it up in a table or by calculation. Although these calculations are based on simple geometry they can look complex on paper. Using computer programs like the one presented in Appendix D can simplify this work. Note that the satellite whose angular location corresponds to the site longitude is found by aiming due south. For example, Anik D1 at 104.5 °W is nearly due south of Denver at 105 °W longitude.

The elevation to any satellite can also be found by calculation, from tables or from satellite finding charts. For example, Galaxy I has an elevation angle of 34.6 degrees and an azimuth of 42.1 °W in Denver. During the site survey it would therefore be found by rotating 42.1 degrees west of true south and then by angling up to 34.6 degrees. A compass would read 209.6 degrees when pointing at Galaxy I. This equals 180° plus 42.1° less the 12.5° correction for magnetic variation. If a tree or any other obstruction were smack in view, this proposed installation site would have to be changed.

Figure 4-2. A Compass. *The compass is one of the basic tools required by a satellite TV installer for locating and aiming at the geosynchronous arc of satellites. (Courtesy of Davis Instruments).*

Figure 4-3. Using a Compass. *This brand is used by sighting with one eye along a set of crosshairs while reading the calibrated scale.*

Figure 4-4. An Inclinometer. *This is the second basic tool necessary for both a site check and an installation. It is used to measure the angle from the horizon to any point in the sky. (Courtesy of Sears).*

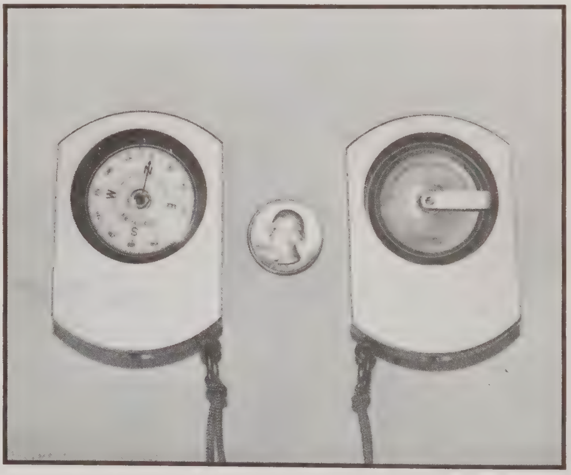


Figure 4-5. Inclinometer and Compass with Viewfinder. *These instruments have a built-in magnifying viewfinder which allows the calibrated scale to be read while sighting in any direction. (Courtesy of Suunto, Inc.).*

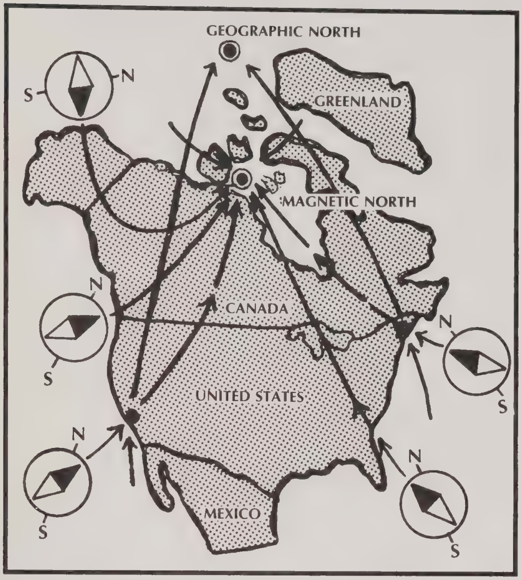


Figure 4-6. True Versus Magnetic North. *Magnetic north is quite far removed from the geographic north pole. It is situated just off the coast of Hudson Bay in northern Canada.*

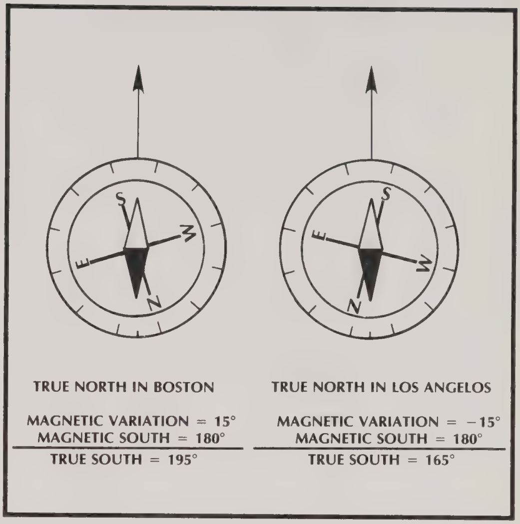


Figure 4-8. Adjusting for Magnetic Variation. *True south is found by aiming a compass east of magnetic south when the variation is negative and vice versa. Magnetic variation is negative when west of the agonic or zero variation line.*

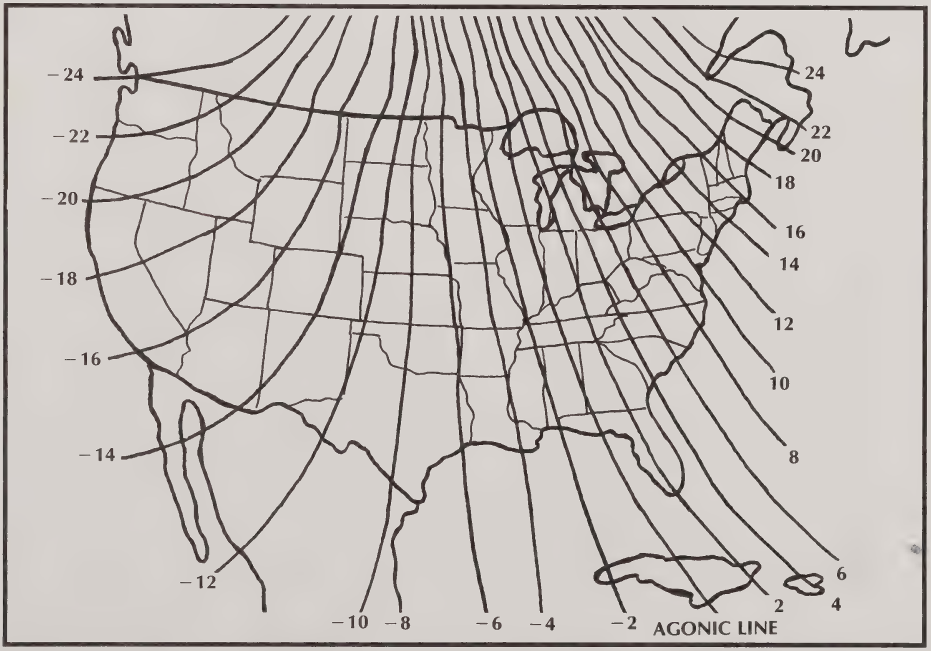
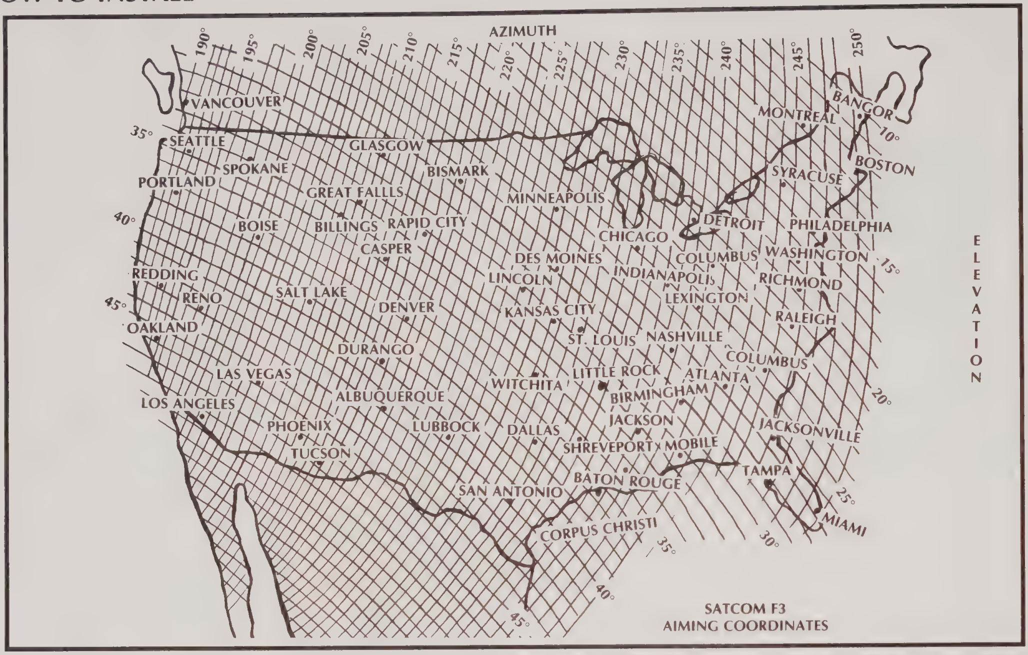


Figure 4-7. Magnetic Variation. *A compass will not point to true north except along the "agonic line" because of the difference in location betweeen the magnetic and geographic north pole. A reading taken with a compass west of this line must be corrected by rotating east to find true south and vice versa.*



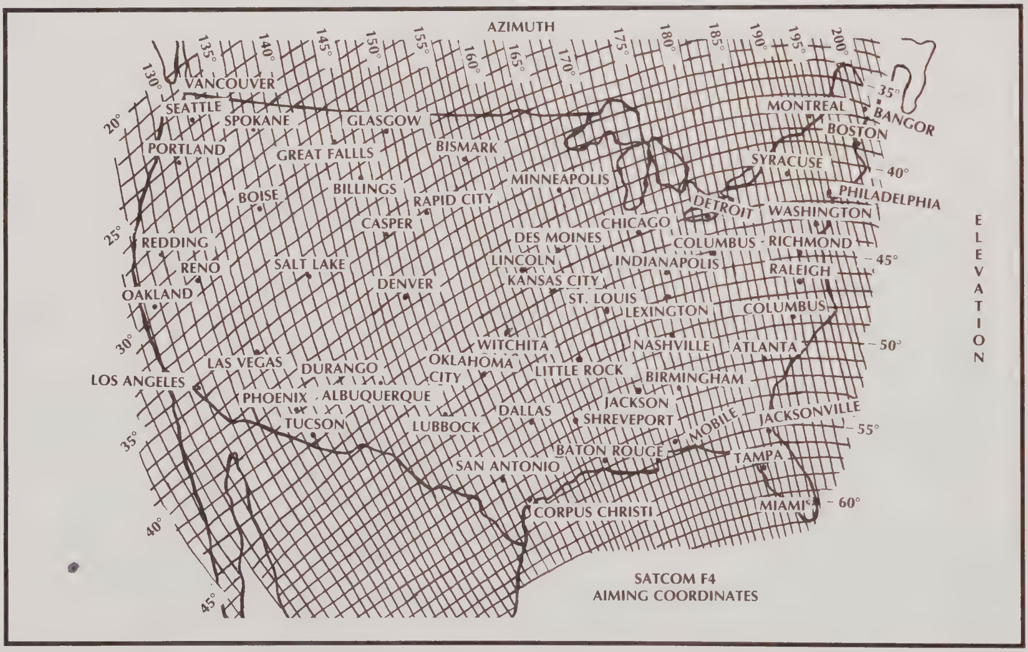


Figure 4-9. Azimuth and Elevation Maps for Satcom III and Satcom IV. *The azimuth and elevation from any location in the continental United States and in parts of Canada and Mexico can be found from this map. These two satellites were chosen because they are near both outer edges of the geosynchronous arc and have many active transponders.*

TABLE 4-2. ELEVATION AND AZIMUTH ANGLES

United States

State	City	Galaxy I Az	Galaxy I El	Satcom IV Az	Satcom IV El
Alabama	Birmingham	243.6	26.1	172.8	50.8
Alaska	Anchorage	163.0	19.7	110.4	2.2
Arizona	Phoenix	217.6	43.9	134.9	40.2
Arkansas	Little Rock	238.5	29.7	163.6	48.7
California	San Francisco	200.3	44.3	126.8	30.3
California	Los Angeles	208.5	46.5	128.5	35.6
Colorado	Denver	222.1	34.6	147.7	38.7
Connecticut	Hartford	250.7	11.8	195.3	40.6
Delaware	Wilmington	249.4	14.5	191.6	43.3
Florida	Miami	252.9	23.0	186.8	59.4
Georgia	Atlanta	245.4	24.0	177.3	50.7
Hawaii	Honolulu	130.8	53.9	95.6	5.4
Idaho	Boise	206.2	36.2	136.6	29.7
Illinois	Chicago	238.6	2.2	173.3	41.4
Indiana	Indianapolis	240.7	22.5	174.8	43.9
Iowa	Des Moines	233.0	26.3	164.3	40.7
Kansas	Wichita	231.7	31.4	157.3	43.8
Kentucky	Louisville	241.9	22.8	175.6	45.6
Lousiana	Baton Rouge	242.1	31.0	161.1	53.4
Maine	Bangor	252.8	8.0	199.8	36.5
Maryland	Baltimore	248.7	15.5	190.0	44.0
Massachusetts	Boston	251.7	10.5	197.2	39.7
Michigan	Grand Rapids	239.2	19.8	176.1	39.2
Minnesota	St. Paul	231.7	23.8	165.8	37.2
Mississippi	Jackson	241.7	29.3	166.7	51.6
Missouri	Kansas City	233.5	28.6	162.0	43.2
Montana	Great Falls	210.9	30.7	144.0	28.9
Nebraska	Grand Island	228.8	29.7	157.5	40.2
Nevada	Las Vegas	211.4	43.1	133.2	36.0
New Hampshire	Manchester	251.3	10.5	196.7	39.0
New Jersey	Trenton	249.7	13.8	192.6	42.7
New Mexico	Albuquerque	223.2	39.3	142.8	42.1
New York	Syracuse	247.5	13.8	189.9	39.8
North Carolina	Durham	248.5	18.5	187.0	48.0
North Dakota	Bismark	223.0	26.7	156.2	33.4
Ohio	Colombus	243.0	26.7	180.0	43.7
Oklahoma	Oklahoma City	232.9	32.9	156.0	46.0
Oregon	Eugene	196.8	37.8	139.6	25.5
Pennsylvania	Pittsburg	245.6	17.6	184.6	43.1
Rhode Island	Providence	251.7	10.8	197.1	40.3
South Carolina	Columbia	247.9	21.0	183.6	50.4
South Dakota	Rapid City	221.7	30.1	152.1	35.0
Tennessee	Nashville	242.2	24.6	173.7	47.8

Texas	Abilene	232.8	36.6	150.7	48.1
Utah	Salt Lake City	212.7	36.2	140.5	33.5
Vermont	Montpelier	250.0	10.9	194.7	38.0
Virginia	Charlottville	247.8	17.5	187.3	45.7
Washington	Seattle	196.9	34.0	131.9	23.5
West Virginia	Charleston	245.2	19.7	180.0	45.5
Wisconsin	Eau Claire	233.4	23.0	168.0	37.7
Wyoming	Casper	218.9	32.7	147.6	35.3

Canada

Province	City	Galaxy I		Satcom IV	
		Az	El	Az	El
Alberta	Calgary	206.0	28.4	142.1	24.7
Alberta	Edmonton	206.1	25.8	143.8	22.8
B.C.	Vancouver	195.7	32.3	132.1	21.9
Manitoba	Winnipeg	225.4	22.6	161.7	31.3
New Brunswick	Fredericton	255.0	5.4	203.7	34.4
Newfoundland	St. Johns	--	--	218.2	28.1
Nova Scotia	Halifax	256.8	4.4	206.8	35.1
Ontario	Toronto	244.6	15.8	185.1	39.5
PEI	Charlottetown	256.6	3.8	206.4	33.3
Quebec	Montreal	248.8	11.0	193.2	36.8
Saskatchewan	Regina	217.4	25.4	153.0	28.7
Saskatchewan	Saskatoon	214.4	24.7	151.1	26.4

Mexico

City	Galaxy I		Satcom IV	
	Az	El	Az	El
Cancun	251.5	32.2	166.3	64.7
Guadalajara	238.7	47.7	132.3	55.4
Hermosillo	222.1	48.6	130.3	44.3
Mexico City	244.4	43.6	139.1	59.9
Montery	237.6	40.8	145.1	54.2

The Islands

Island	City	Galaxy I		Satcom IV	
		Az	El	Az	El
Bahamas	Nassau	255.2	21.2	193.1	60.7
Barbados	Bridgetown	266.6	5.4	242.3	58.7
Dominican Rep.	Santo Domingo	261.7	15.2	216.4	63.7
Jamaca	Kingston	259.2	22.0	200.0	67.7
Puerto Rico	San Juan	260.9	15.8	213.0	63.2
Trinidad	Port of Spain	266.9	7.6	245.2	62.1
Virgin Islands	St. Thomas	263.5	10.4	226.0	60.2

Other

Venezuela	Caracas	265.8	13.1	237.6	67.6

Elevation angles are easily measured with an inclinometer. This instrument can be placed on a long ruler or any other straight edge and used in a similar fashion to sighting a gun. Raise the ruler up until the desired elevation is reached then sight along the length of the ruler to see if there are any obstructions in view. Remember that there must be a clear view to each satellite in the belt. When taking this reading with some types of inclinometers, having a second person reading the scale makes the process a little easier.

Various companies market instruments designed to make sighting the arc even simpler. Some of these products are see-through charts having satellite locations marked. These are mounted on a tripod and pointed due south for sighting the satellites. Others have telescopic view finders which are preset for any geographic location to scan across the entire arc.

Choosing the Best Antenna Site

To visualize the arc, at least three satellites should be viewed, the most easterly, the most westerly and the one highest in the arc. There should be no obstructions hindering a clear view to the satellites. Then an arc connecting these three points should be visualized in the sky. If there is any question about any other satellite in the arc being partially or fully blocked, it should also be sighted. If a clear view is not possible from this location then another one should be tried. If no appropriate location which is acceptable to the customer can be found, a roof mount or long pole mount may have to be considered. Remember, the higher a dish is installed, the more susceptible it is to wind loading and microwave interference.

Customer participation should be encouraged at this point in the installation. He or she should understand that perfect pictures will be obtained only if the view to each satellite is unobstructed. A decision may be reached to install the dish in a location where the signal from one or more satellites will be weakened or lost. Or, if there are minor obstuctions to a clear view at a preferred installation site, the customer may agree to purchase a larger antenna at a higher cost. Remember that if a larger dish is placed behind a partial obstruction, its extra gain can compensate for signal power lost to reflection and absorption.

These plans should include informing the customer of any necessary building permits.

Figure 4-10. Measuring Elevation. *The elevation angle can easily be measured by placing an inclinometer on a straight edge and sighting along it in the direction of the satellite to be viewed.*

Figure 4-11. A Satellite Finder. *The "Viewfinder" is in essence a small polar mount complete with a built- in compass as well as inclination and declination adjustments. An installer views the arc or any obstructions through the telescopic sight. Other such site survey aids include Norsat's "Satellite Finder," Gourmet Entertaining's "Sat-Site" and the "Star King Surveyor" from Gillmax. (Photo courtesy of Focii Antennas, Inc.).*

Distances from fences are usually set by zoning and easements. Typical minimum distances to the dish edge are 15 feet although 10 and 20 foot clearances are not unusual. Changing a planned dish site may involve refiling for a new permit. The customer may also have very strong opinions about the aesthetics of locating a dish in various places on his or her property.

Note that underground utilities such as water mains, telephone lines or electrical cables may be buried at these easement boundaries to conform to local building codes. Planting the pole a few more feet inside the property line than is required may therefore be an intelligent strategy. Utility companies will be glad to send a representative free of charge to help locate any underground utility before it is too late.

The dish site should also be chosen with cable runs in mind. Tunneling under a 10-foot wide driveway may prove nearly impossible. If, as a result, the antenna must be located at a less desireable site where it is not hidden from view, it may prompt the customer to purchase a smaller mesh dish instead of a full blown, solid one.

One additional important factor should not be ignored. Once the dish is mounted, it needs adequate freedom of motion to track the entire arc. If, for example, a dish is set too close to a fence it may either be bent or may demolish the fence before the east limit is set. Nothing can replace careful planning.

Checking for Terrestrial Interference

Many dealers often learn about terrestrial interference the hard way. Once the concrete is set and the installation is completed they discover that half the channels are plagued with severe interference. And profits are down the drain. This is a perfectly avoidable outcome. Also, just because an installation "down the street" had no terrestrial interference (TI) does not ensure that the new one will have the same happy fate. Probably the best advice about TI is "know your enemy."

An intelligent strategy in dealing with terrestrial interference is summed up by the title of the Microwave Filter Company ASTI Manual - The Avoidance/Suppression Approach to Eliminating TI. The first step to be taken is to avoid the interference by correct antenna siting. TI is very directional and can be reflected off metal objects such as a tin roof directly into a dish. But TI like satellite signals is also absorbed by many materials. So installing an antenna even where TI levels are high behind natural shields such as trees or a building may be sufficient protection.

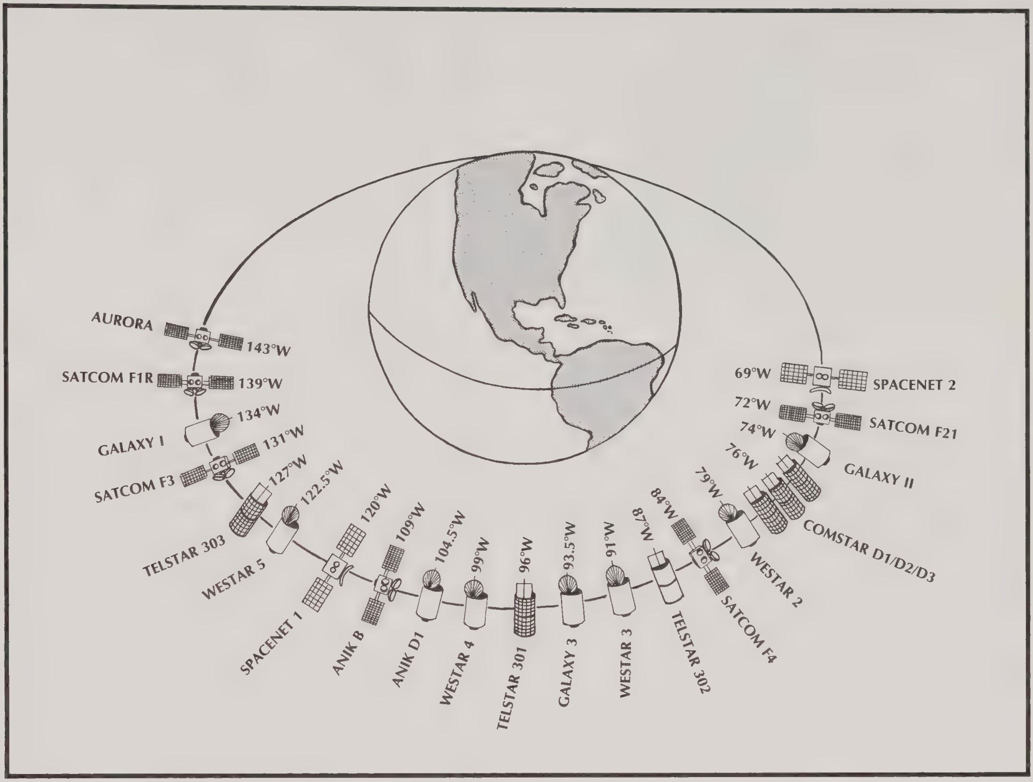


Figure 4-12. Satellites in the Geosynchronous Arc. *This figure shows the location of all the important video broadcast satellite in the North American portion of the geosynchronous arc.*

If an interference-free site cannot be found, the next alternative is to use filters to "notch out" and suppress the interference. However, notching out the interference also reduces the satellite bandwidth and can make obtaining "studio quality" pictures difficult. A second alternative for suppressing TI is to construct the appropriate artifical shields. This strategy is required in severe cases of TI where the system must be installed but it is usually an expensive option. But remember, there is always a solution to a problem.

Methods to Check for TI

By far the most effective method to check for TI is by testing a portable satellite system at the proposed site. A number of small dishes and low cost sytems are now available. These antennas or a collapsible one such as the Luly may easily be transported and may quickly be set up at the site.

Figure 4-13. A Portable Dish for Site Checks. *This 6 foot Echo Star Dish can be easily transported and used for a quick site check. (Courtesy of Echosphere Corporation).*

At least three or four satellites should be targeted since TI can be very directional. It may not show up on Galaxy I but can be strongly disruptive on Satcom IV at the other end of the arc. Sometimes rotating an antenna just a few degrees can cause a side lobe to point at a source of interference whereas before none was detected. Try to set the test dish at the same height the final antenna will be placed; moving down only a few feet may suddenly recruit a fence as a good artifical screen.

All transponders on each satellite should be checked since some forms of interference often affect only a limited number of channels. If TI is present it may be cured by moving the dish. Placing an antenna closer to the ground or, if possible, in a small depression in the ground, reduces its susceptibility to TI. TI does not travel underground! If a location free of TI cannot be found, the time has come to insert selected bandpass or notch filters and see what happens.

Remember, do not confuse a weak signal caused by the antenna being blocked by an obstruction as interference. (In those cases where picture quality has deteriorated in an existing installation, also do not confuse obstructions caused by the growth of new leaves on trees as TI. This can be easily diagnosed because all channels will be affected equally.).

An alternative to testing a complete system is to use a hand-held LNA/feedhorn assembly connected to a downconverter, receiver, TV set or a monitor. It is preferable to have a sensitive signal strength meter in addition to the one often built into the receiver. Turn on all electronics and then scan the test unit in all directions across the sky, not only at the satellites since TI coming from off-axis directions can be detected by antenna side lobes. It must be oriented in both the horizontal and vertical planes so any interfering carriers of both polarities can be found.

Watch both the signal strength meter and the TV screen. If the random white noise or snow on the TV remains unchanged and if there is little or no reading on the signal strength meter then there is no problem. If the screen changes and goes blank, black or white or if black bars or lines appear and if the meter gives a positive indication then some form of TI is present. If the feedhorn is covered up all these symptoms should disappear. If not the test equipment is malfunctioning. Note that if a TV set or monitor is not used, the signal strength meter can be used to detect moderate to heavy TI as indicated by a continuous fluctuation of its readout. However, this method is not very sensitive to light to moderate levels of interference.

If interference is detected, the feedhorn/LNA should be scanned back and forth to find the direction where the meter reading is highest. This will show where the interference is coming from. Orient the feed in all planes to check the polarity of this TI.

If TI had been detected move to another possible site, perhaps one better shielded by natural barriers, and do the same test over again. A logical first choice would be a location where there is an obstruction between the new site and the source of TI. If the interference is coming from behind the antenna, it will not have as great an effect because the dish will block out most of the microwave signal. If no location with a clear view of the arc of satellites and free of interference can be found, it is time to bring in a portable dish to do a more sensitive test. Then microwave and IF filters can be inserted, if necessary, to find a solution to the problem.

Figure 4-14. Using a Collapsible Dish for a Site Check. *Another alternative for a site check is to use the Luly or Toki collapsible dish which is easily transported and set up. Notice the portable test equipment set up on the adjacent table.*

The most accurate results can be obtained by using a spectrum analyser. This device shows the frequency and power of microwaves coming from any direction at any chosen test site. A spectrum analyser is a very effective although costly tool in checking for both in-band and out-of-band TI. However, a low cost spectrum analyser will rapidly pay for itself in saved time for an active satellite dealer.

Note that all these methods of testing for interference have their limitations. The information gathered applies only to TI sources which were operating during the site survey. The 5 to 7 P.M. time period is usually when microwave traffic is heaviest. Therefore, an even better test for TI, which can also be an effective sales tool, is to leave the portable satellite system with the customer for a few days. He or she may notice changes in reception quality at different times during the day or night.

None of these methods will protect a dealer or consumer against common carrier relays which will be turned on at some point in the future. The only protection against some of these future sources of TI is to obtain the necessary information from the FCC. The technique of charting the location and paths of all present and future microwave sources in the vicinity of any installation are discussed below.

The customer should be informed that even though TI may not be present today it is always a possibility in the future. All contracts should have a clause that protects the dealer by either allowing cancellation of the sale if TI is discovered at the time of the site check or by passing along the cost of the necessary filters and installation time to the customer.

Checking for TI before doing an installation is, in short, a protection from hidden costs. It is better to detect TI before than after an installation when filters might have to be purchased. In the worst cases, a system may need to be pulled out at high expense to the dealer. It may be better to occasionally turn down a job than to have a dissatisfied customer. Bad news travels faster than good news. A few botched installations can certainly ruin the word of mouth recommendations necessary for a healthy business.

Charting Problem Sites

A simple method to combat TI even before visiting the site is by charting microwave routes on a local map. The required background information includes all present and planned locations of terrestrial 4 GHz microwave relay stations in the area as well as their transmission routes and frequencies. This information can be purchased from any one of the professional frequency coordination firms, usually for less than $350, and needs to be compiled at most once a year. Or it can be obtained with some more work from either the FCC or local telephone companies.

A map of the region can then be marked with the location of each microwave repeater station. Straight lines are drawn between the sending and receiving sites. Any planned installation which falls too close to any one of these communication routes could be susceptible to TI. Since future sites of relay stations are also marked and since the chart will indicate even those potential sources of interference which might be intermittent, this method can be a very important complement to an on-the-site test.

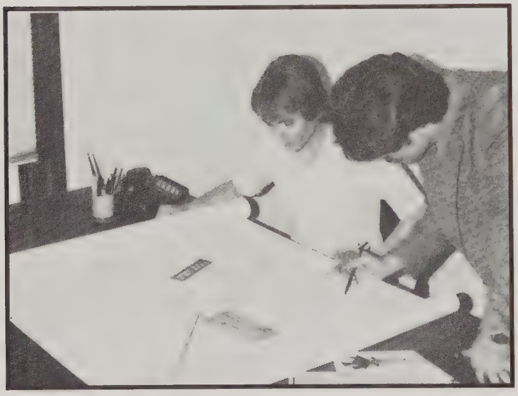


Figure 4-15. Charting TI. *A map can be constructed or purchased which links all microwave towers in the vicinity and shows the frequencies and polarizations used by each relay. (Courtesy of Focii Antennas, Inc.).*

Similar results can be obtained at a reasonable cost from professional frequency coordination companies. For a fee, these firms will provide a computer printout showing the detailed TI environment of a satellite TV installation site as well as planned sources. This includes the expected worst-case levels of interference, their operating frequencies and polarities and their beam directions. The cost is usually around $350 but some scaled-down information can be purchased for at even lower costs. For example, Comsat General Corporation offers the basic information for $99.

Other packages of information including a route map and an intensity map are also available for a nominal fee. The route map, a semi-transparent overlay used with a U.S.G.S. topographical map, identifies and links each relay tower by a line. The intensity map is similar but also includes the expected power of these common carrier relays.

Another option is to register a planned receive-only earth station site for a fee with the FCC. This process may be necessary, for example, when an expensive SMATV (satellite master antenna TV) installation is planned for a condo, apartment complex or hotel. The registration protects this system from future terrestrial relays because it must be factored into their planning. The chances are low that the FCC would allow a common carrier to design a new relay which sends a beam of microwaves directly across a registered $300,000 SMATV or cable TV installation. Frequency coordination firms also offer this licensing service and provide what they call "frequency protection" which warns both the licensied earth station and planned land-based communicator of a potential for interference.

It is important to realize that nothing can replace a site survey. An installation which may be far from the route of a land-based microwave communication path could easily be troubled by a signal reflected off a building or a metal billboard. Or a site directly between two relay towers may have just the necessary natural

screening to avoid any difficulties. Any installation could also easily be susceptible to out-of-band or even ingress interference.

TABLE 4-3. A PARTIAL LIST OF FREQUENCY COORDINATION FIRMS

COMPUCON, INC.
P.O. Box 401229
Dallas, TX 75240
(214)680-1000

COMSAT GENERAL CORPORATION
950 L'Enfant Plaza, SW
Washington, DC 20024
(202)863-6010

COMSEARCH, INC.
11503 Sunrise Valley Drive
Reston, VA 22091
(703)620-6300

MICROWAVE SERVICES
INTERNATIONAL, INC.
266 West Main Street
Denville, NJ 07834
(201)627-7400

Symptoms of TI

Terrestrial interference can come in three distinct forms: ingress interference; out-of-band TI; and in-band TI. These were discussed in detail when considering equipment selection in Chapter III.

Ingress interference has the characteristic of affecting all channels with identical disturbances. It can usually be cured by "tightening up the system," properly grounding cables and connectors, shielding all equipment and using power line filters. The advantage of using a familar test system, i.e. an LNA, downconverter, receiver and TV set, during installation is that it is known to be properly working so time is not wasted in a wild goose chase tracking down a bad connector or some other component. Therefore if ingress interference appears later, it can be diagnosed and easily cured. Even if ingress interference does show up during a site test, it should not be a cause for undue concern.

Out-of-band interference usually is seen at either end of the satellite band and often on either vertically or horizontally polarized channels. It can almost always be easily cured by inserting a bandpass filter between the LNA and downconverter. This should be a regular piece of test equipment on hand. A more expensive

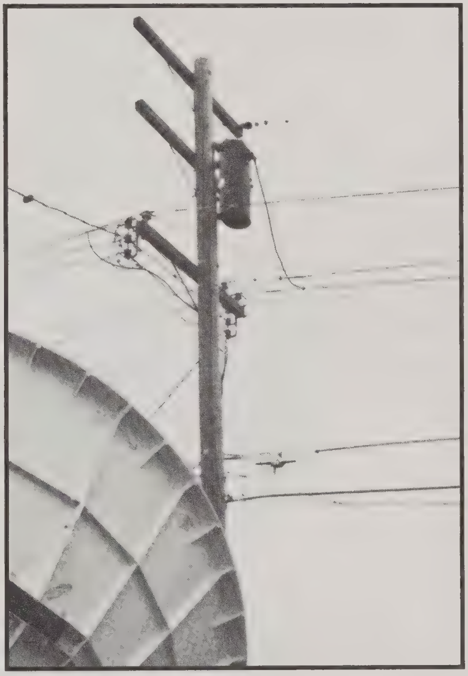


Figure 4-16. A Possible Source of Ingress TI. *This 10 foot Prodelin antenna was installed near power lines. Although these lines do little in the way of blocking microwaves from reaching the dish surface, the 60- cycle power can be a source of ingress interference. All precautions against ingress TI should be taken to eliminate this possibility.*

bandpass filter between the feedhorn and LNA will rarely be required except when TI powers are so high that they overload the LNA (known as driving it into compression).

In-band TI coming mainly from voice and data telephone relays has very characteristic symptoms. There is most often a pattern of disturbance across channels with alternating good and bad pictures. It can vary in intensity from mild sparklies to complete white or black out where the signal strength meter would usually be off the top end of the scale. As discussed earlier, moving a dish to a nearby location behind natural screens is usually the most cost-effective method to cure in-band TI. If this has been unsuccessfully attempted during the initial site survey, other alternatives including the use of C-band and IF microwave traps or artifical screens can generally solve most problems, for a cost.

Natural and Artifical Screening Methods

Terrestrial interference can usually be overcome by a combination of natural and artificial screening methods and, if necessary, appropriate use of filters. Natural screens include trees, buildings, mounds of earth or any other structures already on the site. The best and generally least costly strategy is to make effective use of natural screens before resorting to filters or artifical screens. Natuaral screens would include using houses, garages or trees as protection.

Materials have various abilities to absorb or reflect microwaves and to serve as either artificial or natural screens. Metal is by far the best reflector of microwaves. Most non-metallic structures are generally not very reflective but

Figure 4-17. Using Natural Screening. *Placing a dish in a protected area can shield it from wind as well as interference. Note that if deciduous trees are used, when leaves fall in the winter, TI may return. (Courtesy of the Microwave Filter Company).*

have varying degrees of absorbing abilities. Wood is a poor reflector but has limited absorbing properties. However, an existing wooden structure such as a garage or barn can be made into a reflector of microwaves by lining it with a metal screen mesh. This can usually be accomplished for a relatively low cost. Bricks, cinder blocks, concrete and other masonry products are also poor reflectors but reasonably good absorbers of microwaves. The moisture content of green leaves causes them to be excellent attenuators of TI. But beware using deciduous trees as shields, because when they lose their foliage in winter so goes their value as protection against interfering microwaves.

In general, the higher the dish is installed above the ground the more susceptible it is to TI. The converse is also true. So placing an antenna in a depression or a valley is usually a safe bet for reducing or even eliminating interference. There is a case of an SMATV installation in a motel in California that was so plagued by TI that the least costly solution was to install the 15 foot antenna at the bottom of an empty swimming pool. A new pool was constructed as a lower cost option than curing the interference by another method!

Some materials are optimally designed for absorbing C-band radiation. An example is space cloth, a canvas-like fabric impregnated with carbon to make it resistive to current flow. A similar material coated with metal on one side could serve a dual purpose as an absorber in one direction and reflector in the other. Bulk absorbers can be attached to existing structures to prevent reflection of TI into a dish. Another example of such a material is a carbon-impregnated foam rubber having an array of small pointed pyramids on one side. (It is interesting to note that similar techniques and materials are used by acoustic engineers to absorb sound.).

Metal screens like builders' "hardware cloth" are adequate reflectors. As long as the mesh openings are less than approximately one tenth of the wavelength of the microwaves, the same amount of energy is reflected as it would be by

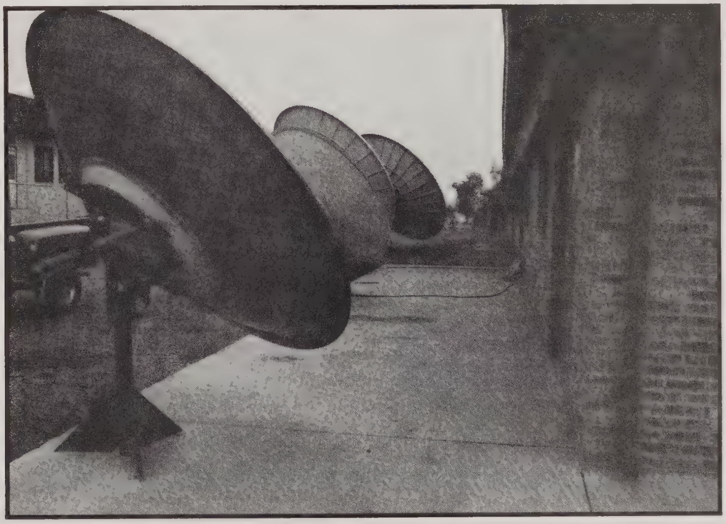


Figure 4-18. Using a Building to Eliminate TI. *These antennas are being shielded from interference by this brick building. This is an excellent solution. (Courtesy of Echosphere Corporation.).*

TABLE 4-4. ABSORPTION ABILITIES OF VARIOUS MATERIALS
(Courtesy of the Microwave Filter Company)

Material	Absorption (dB)
Wooden Wall	5
Brick Wall	10
Concrete Wall (15")	30
Cinderblock Wall	15
4 Feet Thick Earth	30
Evergreen Tree Cluster	25
Tree Cluster - no leaves	10

a solid metal surface. Since C-band signals have wavelengths about 3 inches, openings less than 3/10ths of an inch are adequate. (This is why wire mesh dishes can reflect microwaves as well as solid antennas.).

The first step in finding a screened location for a dish where TI is present is to draw a scale map of the site. The composition of all natural and pre-existing structures is noted. If the direction of the TI source is known, an ideal site may often be easily determined. Occasionally, extra man-made screens are necessary. The least expensive is to attach wire mesh to an existing structure but be careful not to cause more problems by bouncing additional interference into the dish (see below). Or lightweight screens mounted on wooden frames can be constructed. The screen height should be at least three feet above and wider than the dish. And the ping-pong effect which causes interference to be reflected into the dish instead of away from it should be avoided by tilting these screens at a minimum of 30 degrees or more away from the antenna. These man-made structures must be fastened down securely to prevent them from catching a strong wind and being blown into the antenna or causing other damages.

All reflecting barriers should be terminated at the edges with at least a six inch roll of the material used. This prevents creating a sharp edge from which microwaves could be diffracted and bent into the antenna and feedhorn.

Similar effects can be achieved with edge absorbers attached to the rim of a dish (see Figure 4-22). These are made from absorbing materials and reduce antenna side lobes by intercepting some of the "spillover" energy from the surrounding terrain and interfering carriers. Edge absorbers are different from antenna extenders or skirts which increase the reflective surface area of a dish. Since antenna extenders reflect microwaves they must carefully follow the parabolic contour to keep side lobes low while increasing gain. They are a "fix" to build a smaller into a larger dish.

Ocassionally terrestrial common carriers relay video signals occupying the full 30 to 36 MHz wide band from sources such as a local TV station. These will completely wipe out satellite transmissions sharing a similar frequency band. The only completely effective method at shielding against such interference is to screen out these signals with artifical or man-made barriers before they enter the feedhorn.

It should be noted that artificial shielding techniques, while generally more expensive than using filters, do not degrade the satellite signal. Whenever notch filters are inserted into the electronic system, some portion of the bandwidth is removed. This causes a loss of video information often resulting in noticeable picture degradation.

Equipment Selection and the Use of Filters

All the methods for selecting equipment which is less sensitive to TI as outlined in Chapter III should be studied and taken to heart. Carefully chosing equipment can often reduce or eliminate the need for filters.

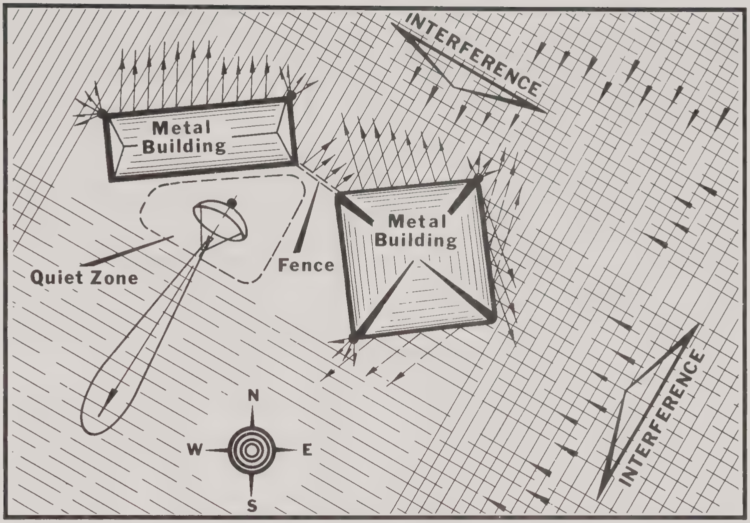


Figure 4-19. Scale Map of Installation Site. *This scale map shows interference coming from two directions. However, if the dish is located behind the two metal buildings and the fence a quiet zone allows TI-free reception of satellite signals. (Courtesy of the Microwave Filter Company).*

Microwave notch filters should be used only when necessary because they eliminate some of the satellite bandwidth and degrade picture quality. However their use is generally preferable to relocating an existing installation or to building expensive and often unattractive screens.

The least expensive notch filters are those operating in the IF range. A wide selection of 60 and 80 MHz filters, traps for more uncommon IFs such as 124 and 144 MHz for the 134 MHz IF DX receiver, and traps which reduce the satellite receiver bandwidth are available (see Chapter III for more details). These are adequate for low to moderate levels of TI ranging up to about 0 decibels relative to the satellite signal. At this relative power level, the picture is usually visible in spite of heavy interference. But IF filters are rarely effective beyond this level, since the receiver AFC begins to follow the interference. However, disabling the AFC and manually retuning the receiver can extend the useful range of traps and watchable pictures can result.

When traps are required in the microwave range, costs can escalate rapidly. If the interfering signal level exceeds 15 dB, a filter between the LNA and downconverter is required. At higher levels of TI, specially ordered, very ex-

Figure 4-20. The Use of Screens for Eliminating TI. *Appropriately placed mesh reflectors can protect a dish from very strong levels of interference. Much more detailed information is available in the MFC ASTI manual. (Courtesy of the Microwave Filter Company).*

pensive filters are required. One filter which may cost many hundred or thousands of dollars is then necessary for each affected transponder and must be inserted between the feedhorn and LNA.

Bandpass filters are not generally necessary since they are built into most good quality LNAs. Threshold extension filters for use in the IF range are less expensive and are even built into some brands of receivers (see Figure 2-44).

In some TI troubleshooting cases, relocating a dish is difficult or impossible, and screening techniques and filters are not completely adequate. We come full circle back to equipment selection. If an adequately large dish having low side lobes had been initially chosen, TI may not have been encountered or would have had a lower impact. A bigger dish also has a higher gain so the carrier to noise power would be increased relative to the interference power. In fact, the use of poor quality equipment can often lead to a mistaken opinion that TI is present. A site survey conducted with a small test dish is useful because it will often uncover cases of mild TI which might not be seen with an oversized test setup.

Planning the Installation

A satellite TV installation should be planned as completely as possible during a site survey. The first step is choosing the dish location. This must be coordinated with mapping all the cable runs to both the receiver and all televisions and with determining how the building will be entered. The type of cable and number of splitters and/or taps needed, as well as the necessary connectors must be determined.

Note that video receivers can be placed anywhere, not necessarily on top of TV sets. If radio controlled actuators and receivers are used, some customers might even decide to leave all this in-doors electronics in a well-ventilated closet.

It is essential that the customer be consulted and be heard during this planning process. Too many dealers will have preconceived notions and may not pay close attention to desires of their customers. Remember, every satellite system should be installed as if it were for personal use. That is the ticket to success.

B. ANTENNA SUPPORT STRUCTURES

Satellite TV dishes and their mount assemblies are almost always supported on a pole. Securing this pole is a critical part of any installation since the dish is often very heavy and is subjected to winds and other environmental stresses. If the pole is solidly set in a true vertical position which is crucial for properly tracking the entire arc of satellites, all the remaining system adjustments can proceed smoothly.

Preparing for the Job

Before work begins on the dish support structure some preliminary steps should be taken.

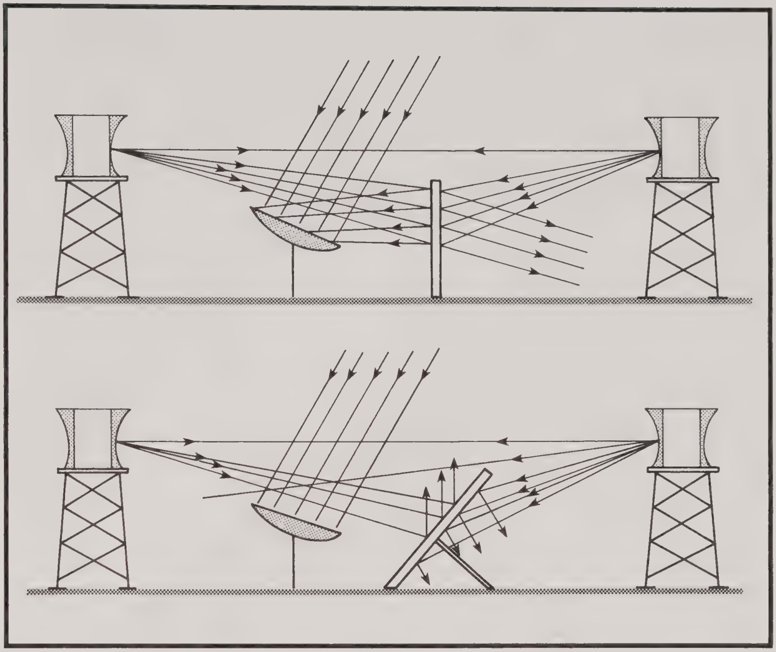


Figure 4-21. Incorrect Use of Screens. *A screen should be tilted away from the dish by at least 30 to 45° to avoid the "ping-pong" effect which can cause even more TI to be intercepted.*

Underground Utilities

Gas, telephone, electric and cable television companies often have underground lines in unmarked areas. Most such utilities will send personnel at no charge to locate these cables or pipes. If a utility line is severed during the digging and trenching portions of an installation, the costs in customer dissatisfaction and time lost are high. And the dealer will probably have to pay an hourly rate to the utility company to have the damage repaired. Also, many states legally require anyone planning excavation to notify the local utility companies of their intent.

Pre-trenching for Conduit Placement

Once the dish location has been chosen and cable runs have been mapped, a few feet of the trench should be dug at the antenna end while doing any other excavating work. This will allow the metal or PVC conduit leading into a supporting pole to be set at the same time other concrete work is done. If this step is overlooked, the cables will have to be exposed and could be susceptible to damage from lawnmowers, weedeaters or shovels.

Figure 4-22. Enlarging an Antenna with Skirts. *Skirts which are used to protect a dish from unwanted noise and interference are non-reflective to avoid degrading performance. This fix, if done properly, creates an antenna having lower side lobes. (Courtesy of Scientific Atlanta, Inc.).*

Poles and Pads on the Ground

A variety of construction methods can be used to secure a pole to a dish site. These include pole supports, pads, pier foundations or combinations of these types. Most require the use of concrete or another strong binding material that will withstand the test of time.

Understanding Concrete

Concrete is a building material which has been around for centuries. Much is known about its properties. New types are constantly being developed for various applications. When prepared and set properly it has tremendous strength and is very durable. However, in-

correct mixing or setting procedures can result in a weak form which can easily crack or disintegrate.

Concrete is like a synthetic rock and derives its strength from its ingredients - gravel, sand and cement. When water is added to a cement mixture, a chemical reaction begins. Setting of cement is not simply water drying out. The cement acts like a strong glue which powerfully binds the gravel and sand together to whatever is in it.

During the chemical reaction, heat is generated. If this heat is lost too fast when installations are done in cold weather, the concrete will not cure properly. Under such conditions it can lose strength and crack. If the surface of the concrete is covered with straw, blankets or other insulating materials, heat will be retained and such problems can be avoided. Calcium chloride can also be added to speed up the setting process; generally 2% by weight calcium is recommended.

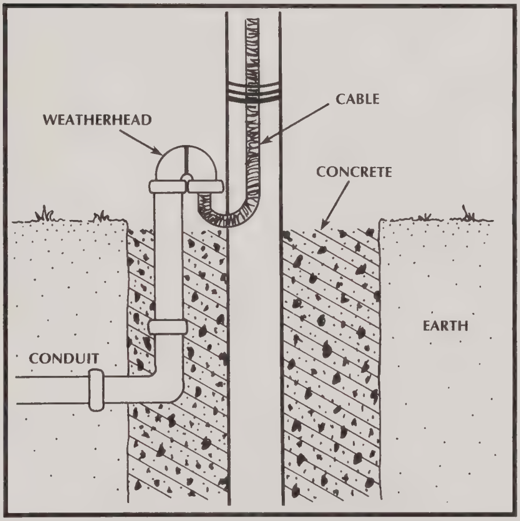


Figure 4-23. The Pole Mount. *This mount has cables running into a 90 degree sweep which has been installed into the concrete base. The weatherhead is attached by a screw fitting and can be removed if necessary to withdraw and install new cables. As a result, all cables are well-protected against damage, water entry and securely held in place. The cable can be secured to the pole by wire ties or by hose clamps.*

Post type foundations can be made from ordinary portland cement or standard premix. Slab foundations having larger areas of concrete should be made from air-entrained portland cement and wire screen. This mixture contains additives that allow microscopic air bubbles to be entrained or trapped. These bubbles are like a lubricant which makes pouring and spreading easier. They also act like tiny shock absorbers which allow the larger piece of concrete to expand and contract without cracking.

Both of these types of cement can be purchased in premixed bags or they can be mixed on site. Ingredients for one cubic foot are listed in Table 4-5.

Other mixes of concrete or replacements for concrete having specifically designed properties are available. For example, QR Inc. sells a special mix called QUIK-ROK® which sets up in 15 minutes at temperatures as low as 20 °F. It is claimed to be stronger than concrete. It expands as it sets thus forming a tight seal; ordinary concrete tends to contract during setting. Similar characteristics are advertised by the makers of another substitute called Sat-Based Cement. Also, for example, Dish Set™ is a concrete substitute. It is a closed-cell, expanding polyurethane foam which sets in about 15 minutes depending upon ambient temperatures. It can be used for pole mounts since it generates force against the pole and the sides of the hole during expansion. It cannot be used in extremely sandy soils. When it is used the hole must be narrow, 1 to 2 inches on either side of the pole, and deeper than normal for this expansive force to have full effect. All of these quick setting mixes do not allow much time for mistakes; be totally prepared before pouring these materials by using leveling stakes.

Freezing, Underground Water and Stability

Underground water is the chief enemy of any foundation. During winter, water at the base of sidewalks, patios or fence supports may freeze around their concrete bases. This freezing water generates tremendous forces which cause the surrounding rocks and soil to shift. When a thaw occurs the water percolates away, soil and rocks collapse inwards and the concrete can twist or settle. This heaving effect is usually not too great a bother for fence posts or other such structures. However, if a pole supporting a dish is moved even slightly off from vertical, tracking of the geosynchronous arc can be ruined.

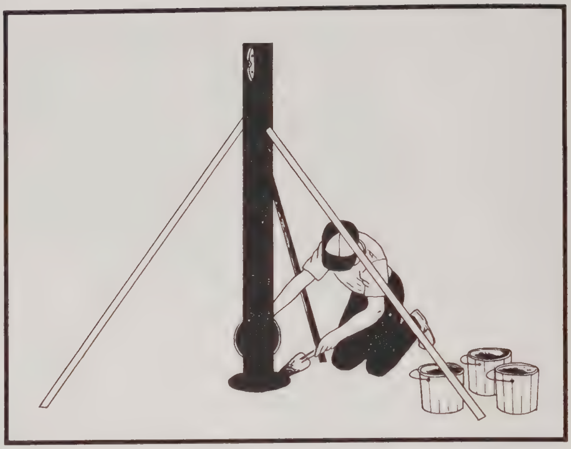


Figure 4-24. The Use of Leveling Stakes. *Leveling stakes keep a pole vertical as the cement cures. They are especially useful when using rapidly setting mixes.*

The frost line is the depth below which no freezing occurs. It varies from 1 inch in southern Texas to over 9 feet in northern portions of the United States. In more northerly locations such as Alaska or the Canadian Northwest Territories special techniques must even be used for any type of construction!

TABLE 4-5. INGREDIENTS FOR VARIOUS TYPES OF CONCRETE

Type	Ingredients in Gallons
Plain Concrete	2.5 - plain portland cement 3 - sand 5 - 3/4″ aggregate 1.25 - water
Air Entrained Concrete	2 - 1A portland cement 2.25 - dry sand 5.66 - coarse aggregate 1.25 - water

Pole or Post Supports

Pole or post type dish supports are the most common variety used today. They provide a strong, stable platform for antennas. But a pole mount cannot be used in locations where the ground is too rocky to dig the necessary hole or where the water table is too high. Remember that water is a good conductor of heat so that a high water table may mean the frost line extends much deeper than normal in a given region. A pole support should also not be used for antennas having larger than 13 foot diameters since the wind forces are simply too great. A 3-legged tower which distributes the force over the whole base should be used. An example is shown here in the illustration of the 16 foot Paraclipse dish.

The hole should be 2 to 4 times the diameter of the pipe. It should extend at least 6 inches below the frost line and six inches of gravel should fill the bottom to allow for proper drainage. Usually between three and eight 80-pound bags of concrete are needed for a typical pole support.

Normally, a pole which extends three feet into the ground and four to five feet above is used. A general rule of thumb is to add one foot extra in the ground portion for every additional five feet of height. For example, a 20

foot pole should be planted 6 feet deep since there are 15 feet of extra length above ground compared to a standard eight footer. Poles set in very soft or sandy soil should be either planted deeper or have a wider concrete base. Once the pole is placed into the ground, it can be partially supported by a few rocks and then kept in its final position with two-by-fours or guy wires. The pole should be perfectly vertical. A carpenter's level at least three to four feet in length or a plumb bob can be used to check this orientation from three or four vertical positions around the pole. These readings should be taken periodically as the concrete is setting. For further stability, concrete should also be added to partially fill the center of the pole. This provides extra stability in high wind areas.

It is recommended that at least schedule 40 steel poles be used. Using schedule 80 or 120 steel is even better. (Schedule 120 is like pipe drillers stem from the oil industry.). If these heavier poles are used there is usually no need to fill the cavities with concrete when setting the pole.

Most dishes typically require 3 to 4 inch outer diameter poles. A half inch metal rod should be inserted through the bottom part of the pole extending out 3 to 6 inches on both sides. Or a piece of rebar with similar dimensions should be welded onto it. This will prevent a dish under the force of wind from causing the supporting pole to break free of the concrete form and rotate. An alternative to using one continuous pole is the implant a sleeve into which the long pole can be bolted. If designed properly, this type of assembly can allow a pole to be re-leveled in case the base eventually shifts.

Most pole supports have no mechanism for making a leveling adjustment once the concrete is set. Often, over a period of time, the effects of wind and water cause a pole mount to shift.

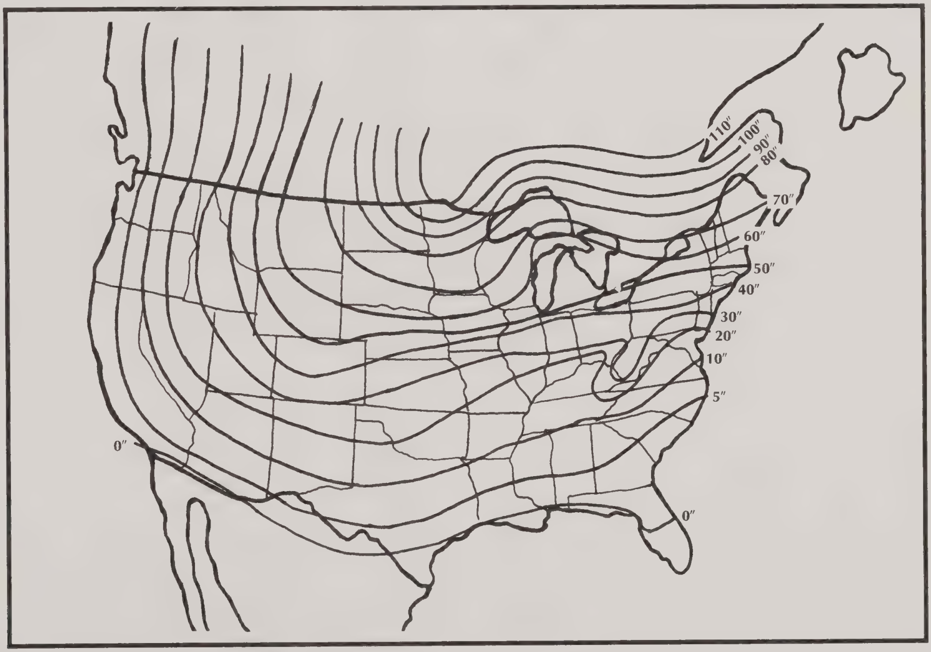


Figure 4-25. The Frost Line. *This map shows the average ground depth above which freezing can occur. This map is based on a yearly average and does not account for variations in soil types or differences in ground water at the installation location.*

Figure 4-26. A 3-Leg Tower Mount. *The weight of this 16 foot Paraclipse antenna would be not adequately supported by a single pole but requires this more stable, 3-leg tower as a base. (Courtesy of Paraclipse, Inc.).*

Remember that a large dish angled towards the southern sky does not have its weight evenly distributed around the pole and this puts quite a large bending force on the support. Without a leveling adjustment, the alternatives are to dig the pole up and replant it with additional concrete, put a new pole in and cut the old one off or try to level it with a piece of heavy machinery such as a truck or jack. None of these are attractive options (see Figure 4-29).

If a dealer is regularly digging holes and planting poles a gas-powered auger similar to those used to dig holes for fence posts is probably a good investment. This can save hours of time during an installation.

Concrete Pads

In those cases where the ground is too rocky or hard to allow digging of a narrow, deep hole, where the groundwater table is too high or when an especially large dish will be installed, a concrete pad should be poured.

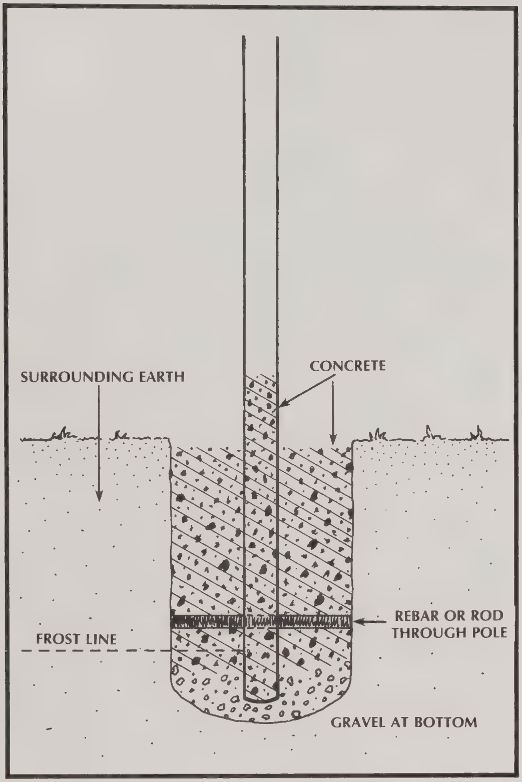


Figure 4-27. Schematic of a Pole Support. *This pole sits in a hole which is typically 2 to 4 times the diameter of the pipe. The bottom of the hole is filled with about 6 inches of gravel to allow for drainage and is below the local frost line. Notice the half inch metal rod extending out from the bottom of the pole to prevent twisting in its concrete base when high winds buffet the dish.*

A pad is constructed by digging a shallow trench, building a wooden form to hold the concrete, adding gravel for drainage, embedding wire mesh for strength and pouring the concrete with the pole and the conduit in place. It is best to recess the pad into the ground so a lawn can be easily mowed and so the customer will not stub his or her toe during the night on a concrete obstruction. When installing a pad in unlevel ground always dig in the high spot never fill in a low spot. If not, the pad will very possibly settle causing the pole to tilt. This is very important.

When the concrete sets, the wooden form can be removed. Note that forms should be made from 2″ by 10″ green lumber. Dry wood will absorb water from the concrete mix and hinder its setting. Also, water should be periodically sprayed onto the surface of newly poured concrete to improve setting by keeping the outside as wet as the inside and thus preventing cracking.

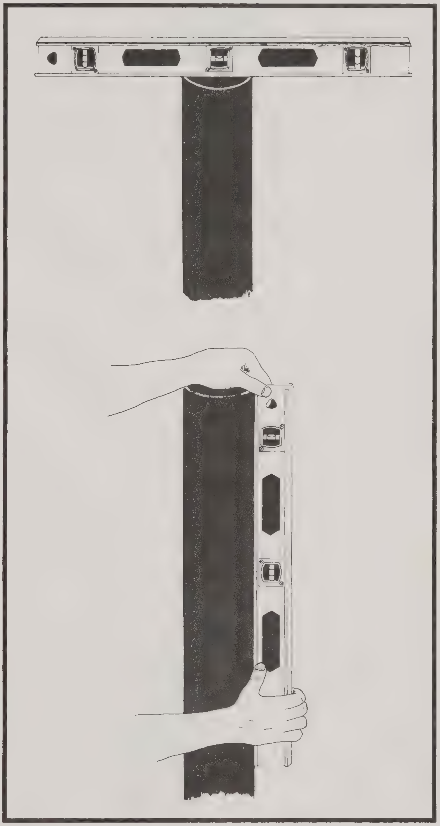


Figure 4-28. Leveling a Pole. *Both the side and the top of the pole should be leveled. The top must be cut flat so that the mount will sit tightly in a true vertical position. The level should be placed on three or four positions around the pole to ensure that it is plumb.*

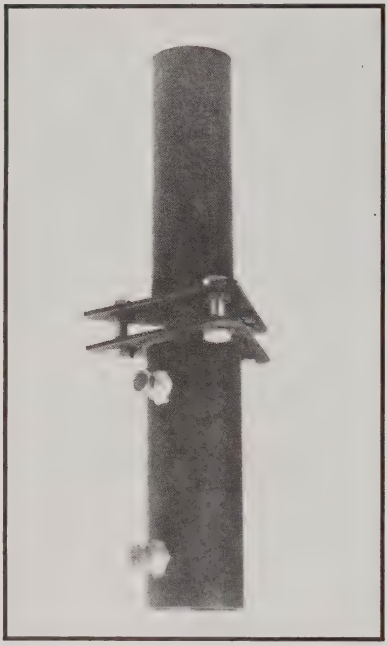


Figure 4-29. Leveling Pole Support. *Poles can be extended and leveled using this adaptor. It can be mounted on a short pole supported in concrete and a second pole can be attached to its top end. (Courtesy of Universal Metal Works).*

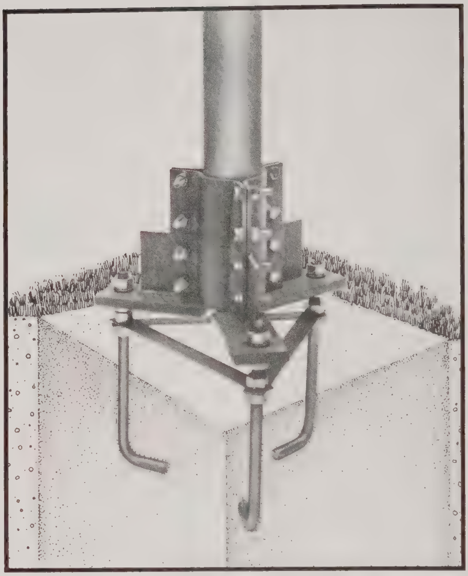


Figure 4-30. Level-Adjusting Pedestal Support. *This suppport is set onto a concrete base or even an existing concrete patio using either the J-bolts provided or redheads. It can be very useful in those cases where the pole in an existing pad has become loosened. The pole can be cut off at its base and this support can be installed in the pad near where the pole had been previously located. (Courtesy of Earthbound, Inc.).*

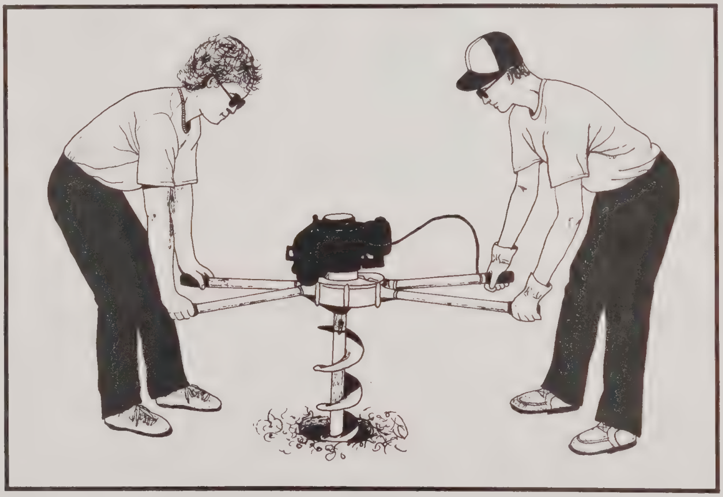


Figure 4-31. Using a Power Auger. *Digging holes with a power auger can save hours of time and difficult work, especially in hard or partially rocky soils.*

A slab foundation supports a dish by virtue of its weight and size. Rules of thumb have been developed to size pads. A pad reinforced with mesh should have concrete at least as thick as the pole diameter. Without reinforcement, increase this width by 50%. The length and width of a pad should be at least half the dish diameter or the measurement from the pad surface to the base of the dish. For example, a 10 foot dish should sit on a pad measuring 5 by 5 feet and should be six inches thick.

Wire mesh used for reinforcement should be at least 8 gauge and have holes spaced no more than 6 inches square. It should be supported about 1/3 the thickness of the concrete below its surface.

A pad mount requires adequate drainage. A sandy soil will require less drainage than a rocky or clay soil which are both more impervious to water. The gravel bed under the concrete should range from a minimum of 50% to 150% of the concrete thickness. For example, a reinforced pad set on solid rock using a 3 inch pole should have about 4.5 inches of gravel and 6 inches of concrete.

The mounting pipe must have two pieces of rebar inserted through its base at right angles. When these are set with the pole in concrete they spread the load over the whole base of the pad for stability. This rebar can be tied to the mesh reinforcement with bailing wire for further strength.

Three Point Pads and Pier Foundations

Three point pads and pier foundations both bolt onto a tripod assembly which holds the satellite support pole. The former is a concrete pad with three or more anchor bolts either preset into the concrete or drilled in after hardening. The latter uses three smaller pads called piers, each one having a small concrete foundation attached to deeply set reinforcement bars and anchor bolts.

Anchor bolts should be made of galvanized steel, 3/4 inches by 24 or 36 inches long. After installation they should extend 3 to 4 inches above the surface of the concrete. This will allow releveling the pole if and when necessary (see below). Note that if the visible portion of the bolt is greased before pouring the cement, clogging of threads will be avoided.

A template conforming to the layout of the base of the pole should be used to place the anchor bolts, generally J-bolts, before concrete is poured or while it is still "green" or soft. The bolts should be carefully kept away from the reinforcing mesh or rebar since any shifting of this supporting structure during pouring can cause them to move out of place. The bolts should never be welded to the rebar since too much heat will cause them to become brittle.

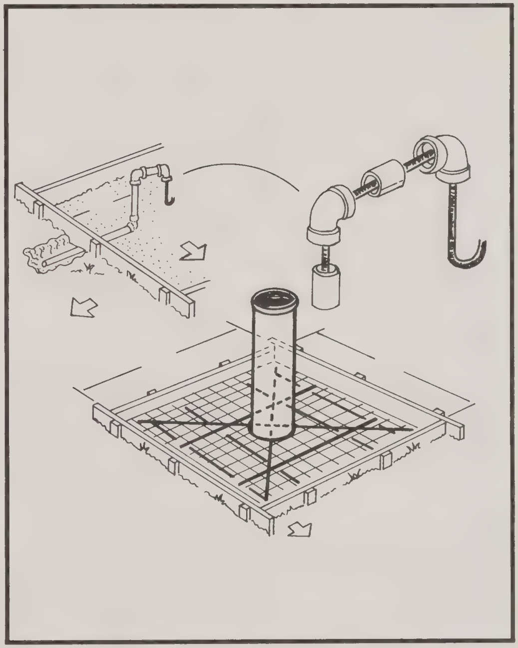


Figure 4-32. Schematic of Pad Support. *This concrete support has rebar or wire mesh for strength and a gravel base for drainage. The pole has its weight distributed by extending rebar or metal rods from its base near the edges of the pad.*

When the concrete is completely cured, 6 inch "redheads" having at least 5/8ths inch diameter can be inserted in a hole made by a hammer drill. Redheads, like some drywall screws, have a collar which folds up when the bolt is tightened and support at least 40,000 pounds of force.

When the dish supporting tripod is mounted, two nuts with lock washers both above and below the attachment points will allow a fine leveling adjustment during installation and at any time thereafter. When using either a pad or a pier to set the tripod, care should be taken to have the three supporting points as level as possible to permit this vertical adjustment to be easily made. Note that two legs of any tripod must be oriented close to an east-west direction to allow a polar mount to be properly installed.

Figure 4-33. Pad Support on a Hill. *This pad support is recessed into the ground on a sloping hill. Notice that it is dug into the higher ground not built onto the lower slope. The pole is secured into about one and a half cubic yards of concrete by rebar which spans the structure and the concrete is reinforced by wire mesh. Gravel at the bottom of the form allows drainage. This pad was installed in the dead of winter when the temperature was 10 °F below zero.*

Some dealers pour three point pads at their stores and then truck the completed structure to an installation site. This technique has the advantage of lowering costs and making winter installations easier. However, slabs can settle, they require special equipment to be moved to a site and they can be difficult to place once at the site. A 3000 pound trailer will crush sprinkler pipes in the ground and cannot often be moved into a customer's backyard. Nevertheless, this method can be a very effective one in certain circumstances to keep actively in business during cold weather.

Combinations of Pole and Pad Supports

A creative installer can construct any variation of pole and pad supports that a given situation warrants. For example, if he encounters an unmoveable rock two feet below the surface in digging a hole for a pole mount, a combination pole/pad support can be created. The pole would still be set into the undersized hole. But a small pad would also be formed around the top of the pole to provide further support. Thus, less concrete can be used and the labor spent in digging the preliminary hole would not be wasted. Be aware that the pole will extend out of the ground higher than normal in this case and mounting the dish on the pole may be a little more difficult.

Dish Supports Not Requiring Concrete

Foundations which use a tripod support design but do not require concrete are also viable structures. Three or more rods can be driven deeply into the ground with a power auger.

Figure 4-34. An Unusual Pad Support. *This pad support, in the mountains of Colorado, was built onto a large granite rock overlooking a hill. A jackhammer was used to insert rebar and J-bolts into the granite base in order to set the foundation. Over 3 cubic yards of concrete were used. Then a hammerdrill was used to make holes for redheads. The dish was assembled piece by piece onto the mount. An aerial run of messengered cable, cable supported by a strong guy wire, spanned 300 feet in the air from the dish to the customer's home across a gully. Since the installation was completed this dish has been struck twice by lightning!*

Then a tripod or even a four-legged assembly can be attached with weather resistant, adjustable bolts. For example, the Earthbound, Inc. system uses a tri-leg steel platform secured with 4-foot long anchors driven into the earth with a power auger. It is interesting that this type of support is not considered a permanent improvement by some municipalities because no concrete is used. Thus, additional taxes can sometimes be avoided.

Roof Mounts and Long Poles

Many installations are simply not possible at ground level because of obstructions blocking a clear view to the satellite arc. The only alternative is to mount the dish at roof level.

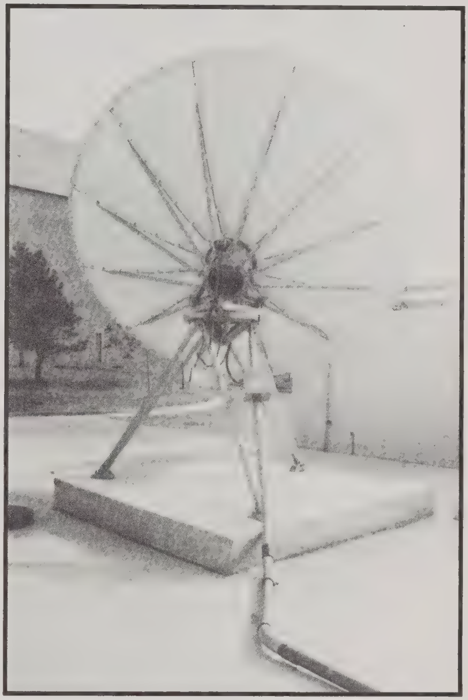


Figure 4-35. Pad Support on Concrete Base. *About 3 cubic yards of concrete were poured on a concrete patio. The pad was secured by redheads to prevent shifting. This 5 meter Scientific Altanta fiberglass antenna is supported by an az-el mount and fixed onto one satellite. Notice how the cable runs are well protected by conduit.*

Figure 4-36. Three Pier Support. *This 20 foot ADM antenna with horizon-to-horizon mount is supported by a three pier pad foundation. Whenever such a tripod supported polar mount is installed it is important that the back two legs be set closely onto an east- west orientation. Fine adjustments to the mount are then made to the telescoping legs to achieve its final position. (Courtesy of Antenna Development and Manufacturing, Inc.).*

Roof mounts are regarded with caution by many in the satellite industry. Roofs are often not designed to withstand weights in excess of normal snow loading or the tremendous upward forces caused by winds on satellite antennas. For example, a 50 mile per hour wind blowing directly into the face of a 12-foot dish generates a force of more than 1200 pounds. This tremendous force could rip a roof off from its rafters! Another hazard is often not considered. If a dish is mounted on a long pole near a area where people walk, snow loaded on the dish may loosen and fall causing injury to those below. In this case, the owner and the satellite dealer can both be sued.

Any dealer considering a roof mount would be wise to pay a qualified structural engineer to analyze each particular situation. If a roof mount is judged to be feasible, the engineer takes responsibility in making this recommendation. Also, in most areas, a permit is required to change the structural integrity of a building.

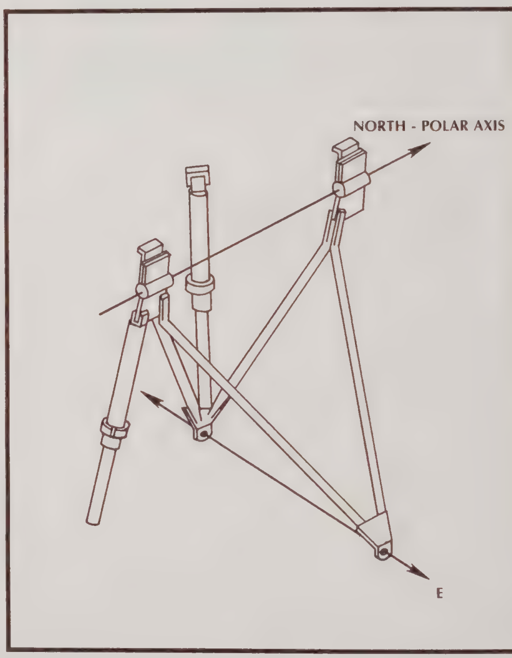


Figure 4-37. Geometry of a Double A-Frame Support. *In order to orient this support and point the polar axis properly, two legs must aligned in an east/west direction.*

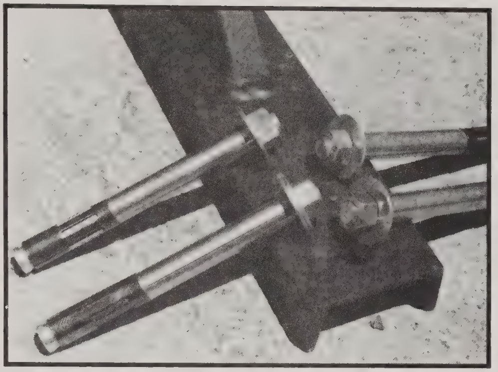


Figure 4-38. Redheads. *These specially designed bolts when inserted into a drilled hole in concrete and tightened, support thousands of pounds of force.*

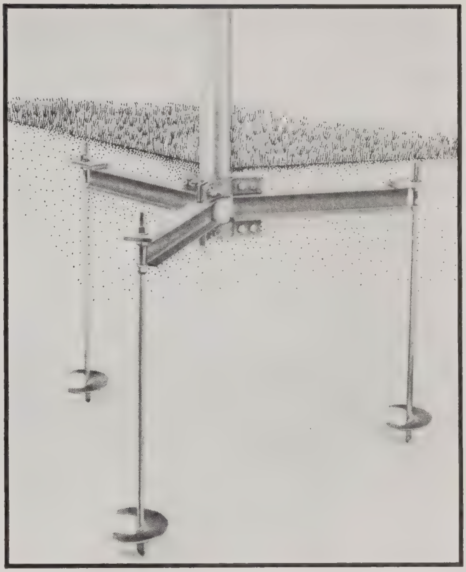


Figure 4-40. A Dish Support Not Requiring Concrete. *This Earthbound System uses a tri-leg steel platform secured with 4-foot long anchors driven into the earth with a power auger. Leveling is possible at any time following installation. Although this supporting system is permanent, it can be removed and installed elsewhere by screwing the legs out from the ground. (Courtesy of Earthbound, Inc.).*

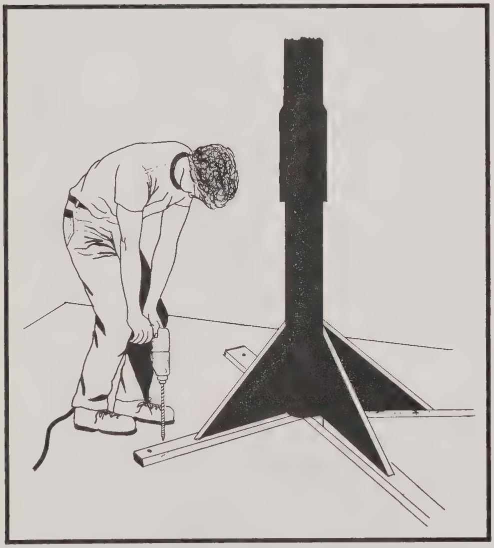


Figure 4-39. Drilling Hole for Redheads. *Once concrete is cured, using a hammer drill and a masonry bit to make holes for redheads is no easy task. The nearby mount was used as a template for lining up these holes.*

A number of companies manufacture welded steel assemblies designed to be used on most types of roofs. These should be attached to as many rafters as possible to spread the load. If the roof has steel beams it is highly recommended that the mount be tied into these members. Two or three guy wires, preferably made from a material as strong as aircraft control cable, can be used to secure the dish for further stability. These will also prevent the dish from landing a hundred yards away if the worst should happen.

Great care must also be taken in breaking roof seals against water instrusion. It is wise to do this with the help of a reputable roofing contractor. Often in doing so the original roofers warrantee is voided and a dealer can become liable for water damage. For example,

even small unsealed holes can allow water to penetrate a roof and ruin a ceiling. Note that a lesson can be learned from local, competent solar installers who have faced and solved related problems for years.

Figure 4.41. Roof Mounted Mesh Antenna. *This Janeil 10 foot mesh antenna has a backfire feed, similar to a Cassegrain feed.*

Roof mounts do have the advantage of being easier and less expensive to assemble than most ground foundations. There are no problems with concrete setting up in the winter and with trenching through frozen ground to lay cable runs. There is a much lower chance of theft when the satellite equipment is mounted out of reach. However, winds are much stronger above a building than on the ground below. And susceptibility to terrestrial interference is greatly increased. A site check which detected none or only moderate levels of TI on the ground may not tell the whole story. Just feet away on the roof TI may be much stronger.

Long pole supports are much less troublesome than roof mounts and can accomplish the same result. Since they are affixed into the ground adjacent to a building, such supports do not require building permits unless these are required to install a concrete foundation at the base of the pole. The structure of the building needs to be considered only in attaching the pole to the adjacent wall. In order to attach the pole to the building it is better to weld tabs to the pole instead of using collars which may slip when high winds attempt to twist the dish.

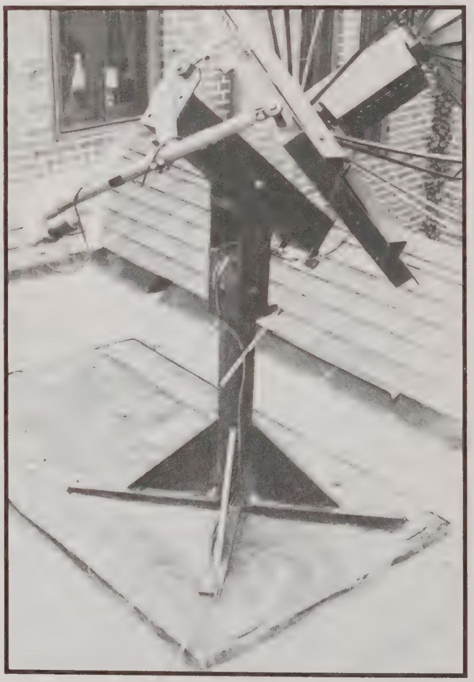


Figure 4-42. Roof Mounted Mesh Antenna. *The Janeil dish was supported by a modified Echo II mount. A qualified roofing contractor laid down two I-beams onto a tin pitch pan. These were attached by all- thread bolts to the roof members and the mount was bolted onto the I-beams. About four inches of tar poured into the pitch pan was used to seal the roof after tweaking was completed.*

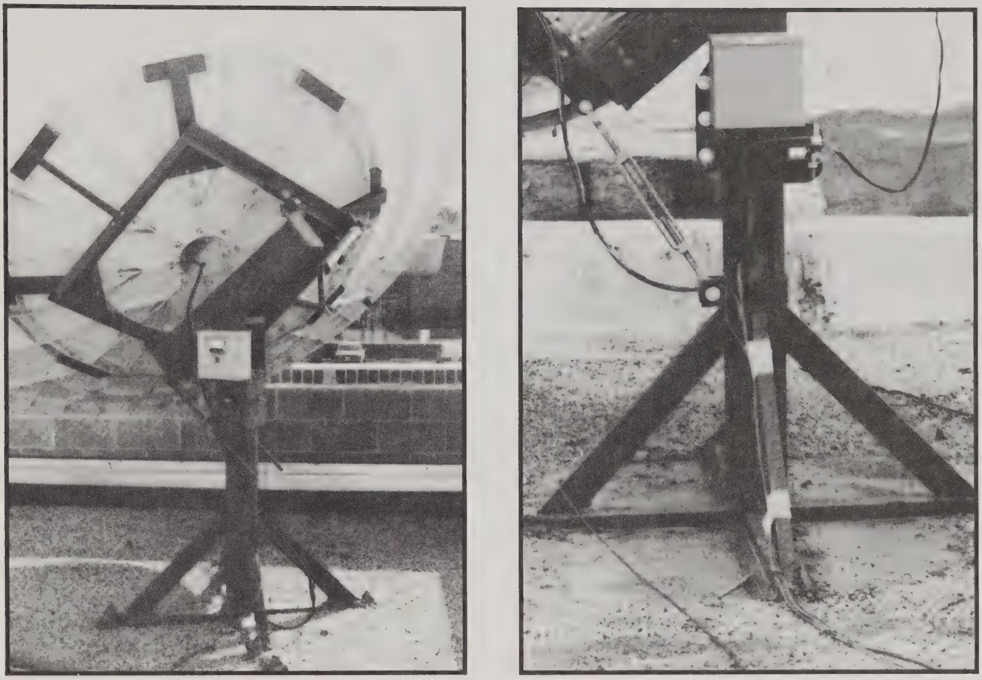


Figure 4-43. Roof Mounted Prodelin. *Both of these antennas, 10 foot Prodelins, were mounted on gravel-top roofs. Gravel was cleared away. Then steel diamond-top ship decking was attached to the steel roof members with 3/4 inch all-thread rod and double bolted. Tar was poured onto the whole decking surface. The dish with the 50-microamp meter was fixed on one satellite. However, other satellites could be targeted by monitoring this meter which was connected by double-run wire to the in-doors receiver. Positions of all the major satellites were marked on the hand-cranked arm.*

There must be at least one attachment point just where the pole meets the top of the wall as this point will experience the greatest torque. The structure of the wall must also be considered before attaching these tabs. There is always the chance that weaker parts of this wall could be damaged as the dish twists or moves under forces of wind or snow.

In general, for every 5 extra feet above the normal 4 or 5 feet pole length, an extra foot should be added to the 3 feet below ground. For example, if a 15-foot length was required above ground level, 5-feet of this total 20-foot pole should be underground. A long pole must be securely attached to one or two points on the adjacent building. The pole should be oversized in diameter by two to six inches to give extra stability against twisting and bending. This requires use of a reduction coupling at the top of the pole. Guy wires should be attached to the base of the mount and nearby support points. Note that a lesson can be learned from the designs of billboard installations which also use long poles. These supports begin with larger diameter poles at the bottom and end with smaller diameter poles near the top.

All of the cable used for both pole and roof mounts running from the dish to the building entry should be placed in electrical conduit. This will prevent the cable from being damaged by ultraviolet light and by other enemies such as birds and squirrels. Many building codes also require its use. Using well-installed conduits also makes an installation look much neater and more professional.

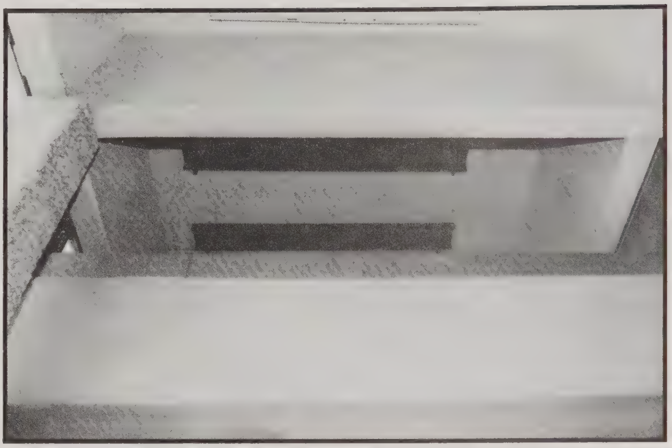


Figure 4-44. Spun Aluminum Dish on Roof Mount. *This 8-1/2 foot Birdview antenna was attached by spanning five rafters with two pieces of channel iron both above and below the roof. The ties were tightly bolted together. Holes were caulked and then tar was poured onto the roof. If a pitch pan had been used under the channel iron, water sealing would have been even more effective.*

Figure 4-45. Ku-Band Antenna on Roof. *Ku-band broadcasts reach the earth with higher power than do those in the C-band. Antenna gain is also higher and beamwidth more narrow as frequency increases. So a relatively small, 1.2 meter (4 foot) dish is large enough to receive excellent quality television pictures. This antenna is also much less susceptible to wind loading. For example, it has 16/81 (4 squared divided by 9 squared) or 20% of the surface area of a comparable 9-footer. Notice the roof support leveling adjustments on the pole. (Courtesy of Northern Satellite Corporation).*

Figure 4-46. Prodelin on Long Pole. *This 10 foot Prodelin sits on a 20 foot free-standing pole which extends an extra 7 feet in the ground. One cubic yard of concrete was used to support the pole. The base of the pole is 8 inches in diameter. This is coupled to a 5-1/2 inch outer diameter pipe which attaches to the dish.*

Figure 4-47. Janeil on 20 Foot Pole. *This 10 foot dish is tied securely to the wall of the building by two welded supports. Notice how neatly the cable run is encased in painted black conduit.*

Figure 4-48. A Long Pole Wall Support. *This 10 foot Kaul-Tronics Trans-10 is attached to both the wall by welded channel iron pieces and to steel girders on the roof by telescoping pipe. The pole does not extend to the ground below.*

C. TRENCHING AND CABLE RUNS

Cable runs between the dish and in-doors equipment should be safely protected and neatly installed. A variety of techniques can be used depending upon the type of cable required, the length of the run, ground conditions, and dish location. For example, trenching is not necessary in conjunction with a roof or long pole support.

Digging the Trench

If a trench is necessary, the first step before digging is to determine where all the water, electrical, gas and telephone lines are located. Utility companies will be more than glad to send a crew out to find these lines and even to help dig to ensure that they are not severed. Customer owned underground systems such as lawn sprinklers can be more difficult to pinpoint. Often a homeowner will not be sure where the pipes are located. It makes good sense to proceed with caution. In some areas where sprinklers are very common, having parts for repairing pipe on hand can be a great timesaver.

The depth of the trench depends upon many factors. If rigid conduit is used there is less risk that an avid gardner will put a shovel through the cable. If the cable is running through an unused portion of the yard, cables should be buried at least 6 to 8 inches under the surface. Generally, a depth of 12 to 18 inches is a reasonable burial depth. Electrical codes in some areas also state that cables should be buried at 12 to 18 inches.

It makes good sense to keep a record of the length, route and gauge of buried cables. This information on a map of the site can be invaluable if an update or repair is requried at some future date. The customer will also find a copy of this record useful if landscaping changes are made.

Remember that leaving unburied or unsecured cables lying around is an invitation to someone with a lawnmover or a destructive curiosity to cause damage.

When a trench is being cut across a lawn care should be taken with the sod. Use either a sharp knife or a flat shovel to cut to a depth of at least three inches on both sides of the trench. Then carefully remove and roll the sod in sections and place them next to the trench. All earth removed after the sod should be placed in a wheelbarrow since it is often difficult to clean loose fill from the surrounding sod with a rake after the trench is refilled. Do not leave the sod above ground for periods longer than a day without wetting it down. Sod can easily dry out and wither.

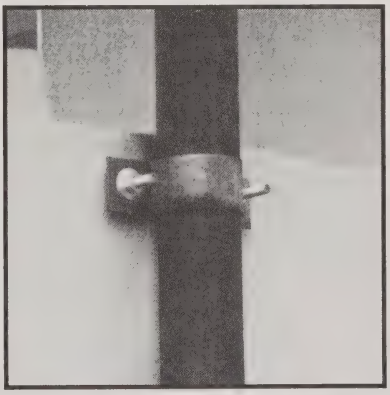


Figure 4-49. Incorrectly Attaching a Pole Support. *This pole is incorrectly attached to a concrete wall by a collar which is not welded to the pipe. Strong winds would be able to twist the dish and pole.*

Figure 4-50. A Long Pole Support and Aerial Cable. *This 9 foot GeoTrac antenna is mounted on a 15 foot pole running up the side of a garage. Aerial cable spanning 15 feet carried the satellite signal into a nearby home. The pole ran through a small hole at the roof edge.*

Figure 4-51. Digging a Trench. *This machine is capable of digging a 1, 2, or 3 inch wide trench from 8 to 12 inches deep at a rate of 20 to 25 feet per minute. It can be a great time saver in certain situations but can damage the sod on a well-kept lawn. (Courtesy of T.H. Riley Manufacturing).*

Figure 4-52. Digging and Burying Direct Burial Cable. *These two tools separate sod and soil to a maximum depth of 8 inches and bury cables. Note that conduit cannot be buried by this method. When such a method is used it is advisable to first be sure that the installation is complete and working correctly. (Courtesy of M.B. Sales).*

Never refill a trench until the installation is completed and it is ascertained that there are no defects in the cable. This precaution will prevent unnecessary reexcavation of a deep trench. Refilling the trench is one of the last steps in a successful installation.

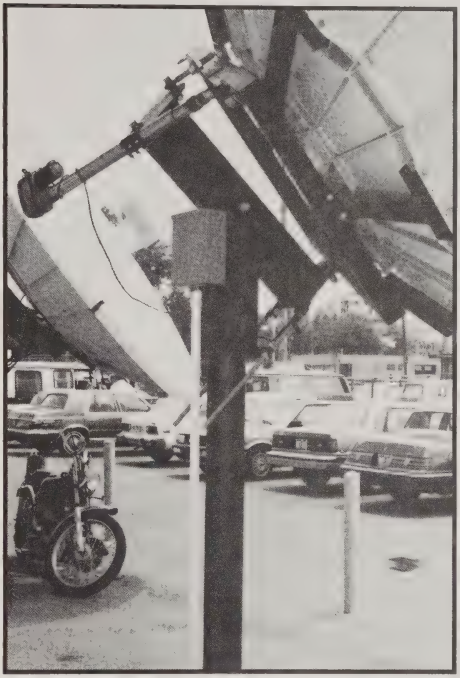


Figure 4-53. Use of Conduit. *This 10 foot Prodelin in the busy parking lot a Denver bar was mounted on a pole which placed the dish well above ground level. The downconverter was protected in a waterproof box and the cables routed in a PVC conduit which was attached to the pavement and directed into the building.*

The Use of Conduit

Many direct burial, multi-piece cables do not necessarily require encasement in a rigid, protective conduit. However, conduit does provide extra insurance against damage. And in certain situations using conduit is strongly recommended. For example, it provides the necessary protection for runs under driveways or roads. If rodents are common, conduit can prevent them from chewing through cables. In areas with excessive ground water conduits can be useful protection. Note that there have been cases where improperly installed conduit has done just the opposite and has become a water trap. As a result, the only solution was to dig up the conduit to drain the excess water.

Local building codes sometimes require conduits when cable carrying power above at set level is used. In these cases, white PVC water pipe or black rolled flexible tubing is not permitted. Only rigid varities like grey PVC or aluminum are permissible.

Conduit should be a least twice the diameter of the enclosed cables. And installing sweeps instead of right angles at corners makes pulling cables into and out from conduits easier. Since sweeps are not available in standard white PVC used for plumbing lines, either grey PVC or standard metal conduits should be used. Some conduits can be easily bent into shape by wrapping it with a material like a heat tape and then by applying heat. Note that if more than four sweeps forming a full 360 degree turn are used, it will be impossible to get cables into or out of the conduit. This will rule out one major advantage of using conduit - the ability to remove and replace cables even after burial has been completed.

Precautions should be taken to prevent water ingress, especially at the dish end. Sections of conduit can be tightly glued together. And weatherheads, which look like a turned down 90 degree bend in the conduit, should have removeable screw fittings and should be used at exposed ends of the run. If the cable ever has to be removed from the conduit and replaced, the screw fittings can be undone to make this task easy. The use of weatherheads as well as correct bonding at joints is very important since any water build-up can ruin cables and corrode connectors. When the conduit runs downhill from the dish to the house, improper installation could cause water to be channelled directly into the house.

Figure 4-54. Conduit from a Long Pole Mount. *This conduit was routed from the roof along a gutter and then into a buried path. Its path along the gutter prevented it from being tripped over and damaged.*

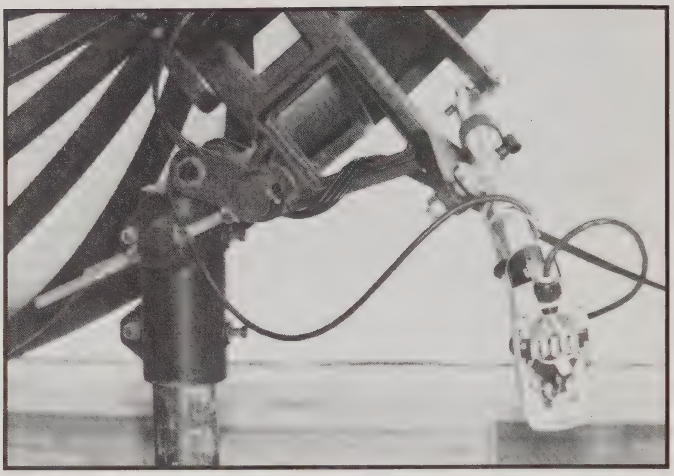


Figure 4-55. Drip Loop. *A drip loop allows any water build-up caused by melting snow, rain or condensation to drain away from components such as actuators. Notice how the cable here has its lowest point below the actuator motor.*

Note that when using PVC type conduit, be careful not to allow the solvent or cement to drip onto cable insulation. Some types of insulation can be dissolved by these solvents and damage to cables can result.

When pulling cable through conduit, do not lay the cable on the ground as it can pick up debris making the job more difficult. A "fish tape," a piece of rigid wire, can also be used to pull cables through conduits. It is inserted at one end and the cable is attached to it at the other end. Cables can also be lubricated with a liquid soap to make it slide through the conduit more easily. If the cable is too short to span the entire length between the dish and the receiver, never splice two cables together. Start again. Run a complete and intact cable which is long enough. This splicing not only would increase resistance to current flow, but would also present a perfect opportunity for cable breaks to occur in the future or for water to enter and short out the system.

All the cables can be attached to the supporting pole with wire ties or hose clamps. Drip loops can also be built into the cable terminating areas to channel water away from the downconverter. A drip loop is simply a loop in the cable which has its lowest point below the connectors, a hole in the wall or an entrance in the bottom of a waterproof box. Any water from rain or melting snow and ice tends to collect at this low point and drip away.

Types of Cables for Satellite TV

Cables for satellite TV systems can be purchased as multi-run, direct burial lines or can be assembled from the various component cables.

Direct burial lines typically have either two RG-59 or RG-6 coaxial cables or one coax and a four wire downconverter power run, a triple wire polarization/feedhorn control run and a 5-wire actuator power/control cable. These are usually swept tested to ensure that there are no breaks or discontinuities.

TABLE 4-6. RECOMMENDED COAXIAL CABLE SIZES

Maximum Useable Frequency (without amplification)	Cable Lengths (feet) 80	150	300
70 MHz	RG-59	RG-59	RG-6
950 MHz	RG-6	RG-6	RG-11
1450 MHz	RG-6	RG-6	RG-11

The polarization control line should have three shielded wires of the minimum gauge shown in Table 4-7.

The actuator line consists of two #14 gauge 36 VDC motor wires and three #20 gauge sensor wires (this includes a ground wire). Such cables are usually adequate to runs of up to as long as 200 feet. For longer distances, #12 gauge should be used for power cables.

TABLE 4-7. WIRE SIZES RECOMMENDED FOR POLARITY SELECTION DEVICES

Maximum Cable Length (feet)	Wire Gauge (shielded)
80	20
150	18
Longer Runs (to 300 feet)	16

Minimizing cable runs has a number of advantages. Shorter cable runs mean less trenching is require and less money need be spent. When runs exceed 300 feet, special heavier gauge lines must be used to prevent problems such as servo hunting or incorrect actuator counting (see troubleshooting chapter). If a dish has been sized too small for a long run, there might even be a need for a line amplifier to boost the IF signal power.

Direct burial cables can have an extra line or two for some applications. For example, if the same coax carries the downconverter power

TABLE 4-8. WIRE SIZES RECOMMENDED FOR ACTUATOR CONTROL CABLES

Maximum Cable Length (feet)	Wire Gauge Motor	Shielded Sensor
80	16	20
150	14	20
300	12	20

and the IF signal, a second coax or power line is unnecessary. Or if an actuator is not being installed, the actuator wires will be redundant. These extra lines should always be included so extra components like an actuator can be added in the future without additional trenching. Also, if problems with ground loops arise, having an extra line to make a common ground connection can prove very useful.

Working with cables can be difficult in very cold weather. Some manufacturers supply an especially flexible cable for these situations. This is a very useful type of cable in cold weather installations (more details on cold weather installations are presented later in this chapter).

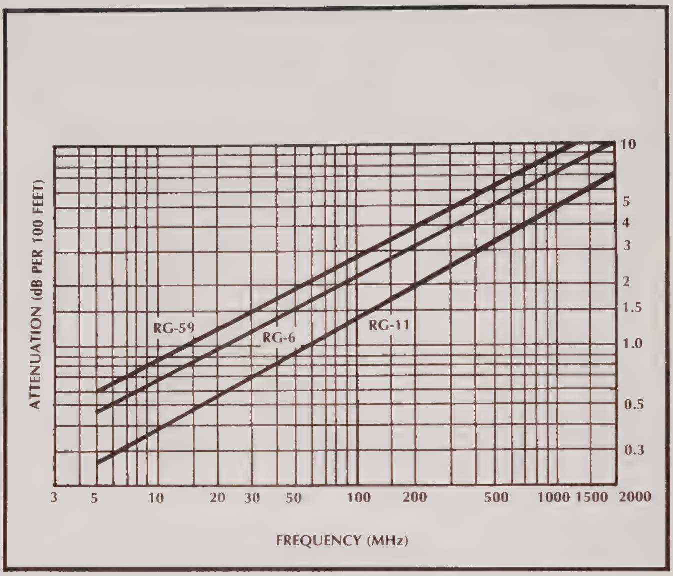


Figure 4-56. Cable Attenuation Chart. *The amount of signal lost per foot in some cables used for satellite TV systems is graphed here. The attenuation per foot in decibels for the range of frequencies normally encountered is easily read from this graph.*

The Entry into the Home

Most customers prefer to have all cables hidden from sight. Holes drilled in a home should be as small as possible and well caulked when the job is completed. If entry is into a crawl space, holes may be drilled below the ground level if they are very well sealed but drilling above is recommended. Always have sets of masonry and wood bits on hand. Many older homes have very thick walls so that extra long wood bits (up to 18 or 20 inches) should be available during an installation. Holes should be drilled at least 12 inches away from any electrical outlets to avoid hitting power lines. And be careful drilling near bathrooms, kitchens or other places where plumbing may be close and where damage can be done.

Drill from the inside of a wall to the outside, not the other way around. And only drill after all measurements have been taken and the path of the bit is known. When possible, use wallplates similar to those on electrical outlets. A wide variety of types are available at electrical part distributors. Cables fed either into an attic or crawl space can be fished up or down into a wall to make an unobtrusive entry.

When carpet must be disturbed, cut a small x with a razor blade or an exacto knife through both the carpet and padding so later if the system or cable is moved the rug can be easily repaired. A drill can often catch on the rug pile and tear a wide area opened or ball up padding. Never run cables under a rug. The tacks used to attach the rug to the pad and floor can also easily short out cable. And cables cause bumps when under rugs making tripping all too easy.

When cables are routed through either crawl spaces or attics, they should be attached to rafters or floor joists. Special staple guns are made to fit onto the cable surface to avoid damaging the conductor. For example, the

Arrow T-25 staple gun used with 9/16 inch length round-top staples, which are made especially for RG-59 cables, makes this job easy. The T-15 staple gun can be used with 18 or 20 gauge wires and cable. Small plastic clips which are designed to be nailed onto a wall are cosmetically attractive.

Never run cables parallel to electrical lines. This can pick up ingress interference such as 60-cycle hum.

D. ASSEMBLING THE DISH, FEEDHORN AND LNA

The dish, feedhorn and LNA are the most critical components of a satellite system. If they are not selected or installed properly, the best receiver and modulator in the world will not improve picture quality.

Assembling the Dish

Each antennna has its own set of assembly intructions. These instructions should be carefully read at least twice to determine if any special tools or manpower will be required or if there are any unanswered questions. Usually, most of these questions can be solved by simply beginning to assemble the dish, but occasionally a call to the distributor or manufacturer is necessary. Be sure that all parts are accounted for before proceeding to the job site.

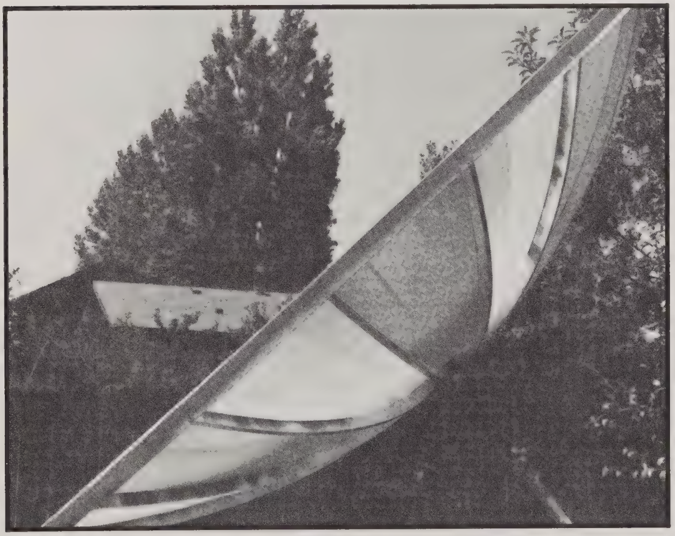


Figure 4-57. Lip-Sighting a Dish. *Sighting along one rim of a dish to the other to be certain sure that they are perfectly parallel is a very effective method to determine if there is any warpage.*

Spun or stamped dishes are most often delivered in one piece so the reflector does not need to be assembled. The most important step is bolting the mount and antenna together. In cases where holes have to be drilled to attach a mount, it is critical that this mount be centered. Do so by crossing two strings each tied to two opposite corners of the mount. Then line up their intersection with the dish center. Spun dishes always have a hole precisely in their center where they have been held by a lathe. Stamped dishes often have a hole for the buttonhook or an identifiable center point from the manufacturing process. . It is smart practice to tighten all bolts or screws on any antenna only after all are in place to avoid warping the dish. It is just as important not to overtighten these bolts

which can cause a 4 to 12 inch dimpling or indentation and a gain decrease. Rubber spacer washers or grommets are sometimes provided to act as shock absorbers and should be used. If the dish is aluminum and the mount is steel, it is even more important to insert these rubber grommets to prevent electrolysis action between the dissimilar metals. In time, this type of corrosion would make the points of attachment wear away.

There are two accurate and very simple techniques used to make sure that dishes are not warped either during manufacturing, shipping or assembly. First, to lip-sight a dish look along one rim so that the other side is in the same plane. Both rims should line up as two straight lines one ontop of the other. Second, the crossed string method involves using two or three strings taped or otherwise draped over the outer edge of an antenna. If these strings either mesh together or are separated, the dish is warped. They should just lightly touch one another. Note that using three crossing strings makes it easier to locate the center point.

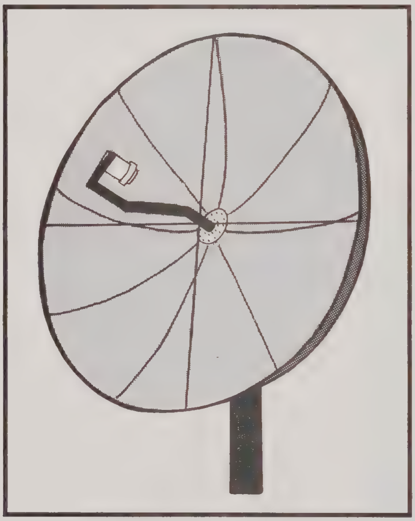


Figure 4-58. Stringing a Dish. *Running two or three strings across a dish from the rims, like sighting a dish, is an effective method to determine if an antenna is warped. If these strings are meshed together or are separated, the dish is warped. If a tripod supports the feed assembly, sighting from behind the dish through the hole in its center should line up the feedhorn exactly with the string intersection.*

Fiberglass dishes should be assembled on a flat surface to make sure that all sections go together with a perfectly flat rim. Again, do not tighten bolts until the assembly is completed. This allows each section to be lined up in a smooth interface with the adjacent ones. Some fiberglass dishes can be assembled on the mount. In this and all cases, the bolts are tightening progressively from the center to the outside to make the dish expand outwards from the center.

Mesh dishes can be assembled on any surface. Doing the work on grass or a soft material such as the cardboard boxes used for shipping avoids scratching the paint. It may also be convenient to rest the central hub on a stand like a small table or a garbage can to make attaching all the ribs, panels and bolts or screws easier. Note that if wind clips are provided they should

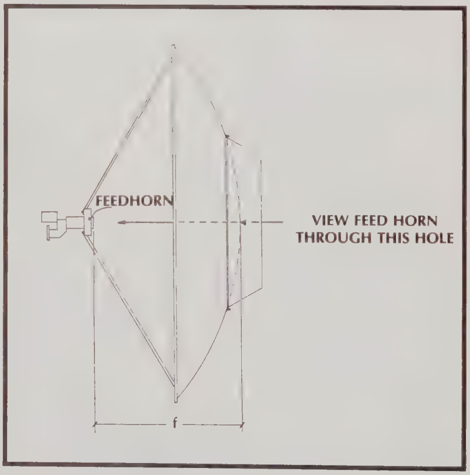


Figure 4-59. Sighting a Stringed Dish. *When looking from the back of a dish to the point of crossed strings, the feedhorn should be located directly on center like sighting crosshairs on a gun.*

Figure 4-60. Double Bolting. *Two nuts were used on the pivot point of this antenna to ensure that the bolt would not loosen over time.*

Figure 4-61. Lifting a Fiberglass Antenna. *Large fiberglass antennas can be very heavy and often require a crane to be lifted into position. In this case, the dish was accompanied by both an installer and the mount.*

be used. There have been cases of panels popping out partially or completely in strong winds. Some installers run an extra, small wire through each section near the rim to provide further protection against wind damage.

Setting a Dish on the Pole

Except for fiberglass dishes, most can be easily lifted by two people. Fiberglass dishes are much heavier. Especially large ones over 12-feet in diameter usually require four people to share the lifting. In some cases, a crane may even be needed to complete the job. This extra weight has prompted some manufacturers of fiberglass antennas to design their dishes so they can be assembled directly on the mount after it has been set on a pole.

Other types of dishes can also be installed by having the mount first set on the pole. Then the completely assembled antenna is lifted into the correct position where the attaching bolts can be inserted. The method chosen is simply one of personal preference.

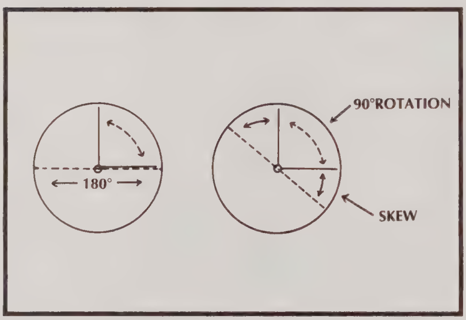


Figure 4-62. Servo Motor Probe Mechanical Limits. *Servo motor probes in mechanical polarizers have at most a 180 degree possible range of movement. The mechanical limits must lie beyond both polarity direction settings.*

Spun or stamped dishes often have easily deformed surfaces which can be dented or scratched. Such dishes should be lifted into their final position separately after its mount has been attached to the pole. This will avoid bending the rim at the points of lifting. Damage can also occur before the actuator arm is attached since the dish can often move freely and strike other objects.

Assembling the Feedhorn/LNA Structure

The feedhorn and LNA should be bolted together before being installed on the buttonhook or tripod support. Two important instructions should be carefully followed. Never touch or bend the probes on either component. They

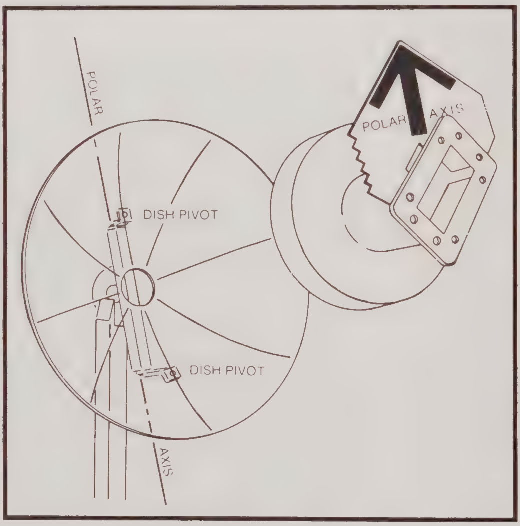


Figure 4-63. Orienting a Feedhorn/LNA. *Chaparral Communications makes a useful device called the Arrow ™which aids in properly aligning a ferrite or servo motor feed. The point of the arrow is lined up with the polar axis on the mount and guarantees that the motor will not be driven against a mechanical limit and damaged. This particular one is used for orienting the Twister™ and Polarotors™. (Courtesy of Chaparral Communications, Inc.).*

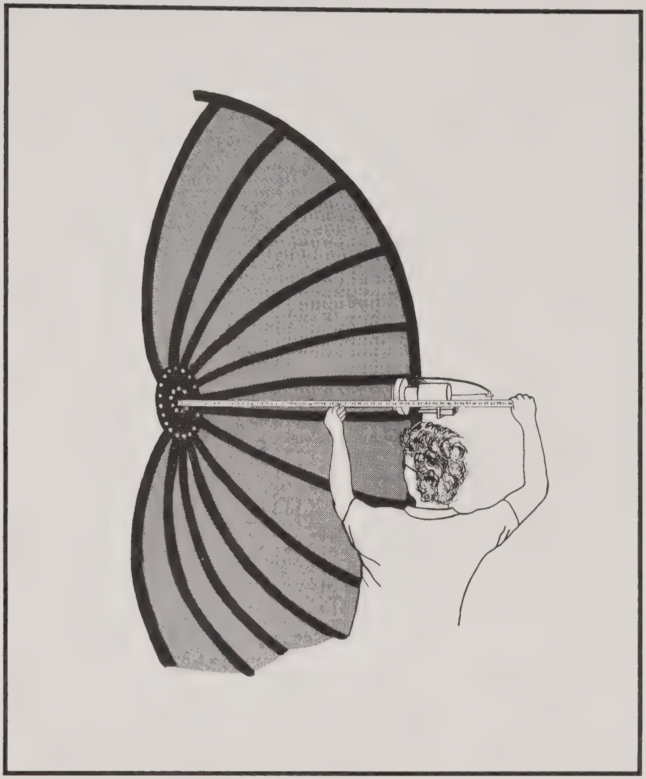


Figure 4-64. Setting the Focal Length. *Setting the correct focal length is very important in optimizing reception of satellite broadcasts. This measurement should be taken from the antenna surface to the front of the feedhorn throat.*

are finely tuned at just the correct location and any tampering will change the VSWR, the amount of signal reflected and lost at their inputs. And always use the gaskets provided for insertion between the flanges. These protect against water ingress. But never use any sealant between these gaskets because there must be metal to metal contact in these joints. The distance between these joints should not be increased as this would alter the impedance match between the waveguides. The bolts around these flanges should also be evenly spaced and then tightly secured.

Most feedhorns have plastic covers with small holes to allow any condensed water to escape. These should always be used. Occasionally, when a feedhorn has been left upcovered, wasps or other animals have built nests inside. Needless to say, this ruins reception of microwaves.

Correctly Aligning the Polarity Selection Probe

When using servo motor feeds it is imperative to align them so their 180 degree possible rotation motion is centered around the two signal polarizations. The servo motor can be hooked to a control device such as a receiver or an actuator when applicable to control where

the servo limits are set. When properly installed, the motor should rotate 90 degrees between horizontal and vertical polarity signals and still have extra room to move on either end of this movement. This will allow making the skew adjustments necessary when tracking between satellites with slightly different polarization orientations. Most importantly, it will prevent the motor from sitting on a limit and burning out either the motor or the timer in the receiver. This procedure will also serve to check if the probe motor is working properly.

Chaparral Communications, Inc. makes a very useful device called the Arrow® which is used to orient the LNA flange approximately 45° from the polar axis. Since the probe rotation is set relative to the its body, this orientates the LNA and feedhorn in the correct position.

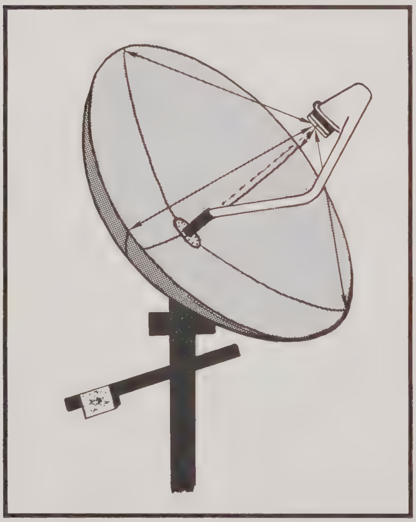


Figure 4-65. Centering the Feed. *The feed can easily be centered by making sure that three or four measurements from points around the dish outer edge or rim to the feed are an equal distance.*

Properly Aligning the Feed System

One of the most critical yet most often overlooked procedures in installing a satellite system is adjusting the feed system for correct focal length and feed center alignment. In order to maximize the performance of the entire system, great care should be taken to ensure that the feed is properly installed.

Always follow the manufacturer's installation instructions for finding the correct focal length. Each antenna will have a unique f/D ratio and focal length. To illustrate, assume a 10 foot reflector has a 35 inch focal length. This must be measured from the center surface of the dish to the front edge of the feedhorn. For a Chaparral Polarotor®, the focal point on the feedhorn is 1/4 inch inside its throat. So this 35 inch measurement would be taken as 34.75 inches to the front surface of the feedhorn.

Centering the feedhorn is just as critical as setting the focal distance. At least three methods can be used to do so:

1. Measure from the outer lip of the reflector to the throat of the feedhorn from four differenct points. These points should be at 3,6,9 and 12 o'clock positions, and the resulting measurements should be very similar in each case. If not, the feed should be moved until the measurements are nearly identical.

2. Cross the dish using two pieces of string at right angles over the dish surface to each other. This is similar to the method outlined above for checking for warpage. Dishes such as spun aluminum or Hydroform varieties which have a hole in the center can now be tested for feed centering. String two more pieces of twine this time behind the dish. They should cross over this hole. Sighting along both crosspoints should target the center of an aligned feedhorn.

3. Use a focal finder, a relatively inexpensive item, to center the feed system. Insert the focal finder into the throat of the feedhorn and adjust until it touches the center of the dish.

When using a buttonhook feed support, 3 small cables with S-hooks that attach to the feedhorn at the 12, 4 and 8 o'clock positions can be used. The other ends of these cables are attached to the antenna with metal clips that slide onto the outer lip of the dish. This "wind kit" allows for centering by tightening or loosening the different threaded eye hooks.

Note that every feedhorn is designed to work optimally with a given f/D ratio. The proper unit should be selected for best performance results. For example, the Polarotor®I is designed for use on reflectors having 0.35 to 0.45 f/D ratios. In order to use this feed on an antenna having a 0.32 f/D ratio or deeper, the Chaparral Gold Ring® should be installed in the throat of the feedhorn. Tests have shown that this yields an increased gain of 0.9 dB on an antenna having a 0.3 f/D. That extra gain can be the difference between having a few sparklies or no sparklies in a poor footprint area or when using a small aperture antenna. Note that if improvement is not noticed when the ring is added, the reflector is probably warped and hence not a true parabolic shape or the dish has an f/D higher than approximately 0.32.

Figure 4-66. The Focal Finder. *This instrument can be used to accurately measure the focal length and center the feed. It fits snugly into the throat of most feedhorns. The telescoping central rod should then extend to the center point of the dish. Its length should equal the correct focal length.*

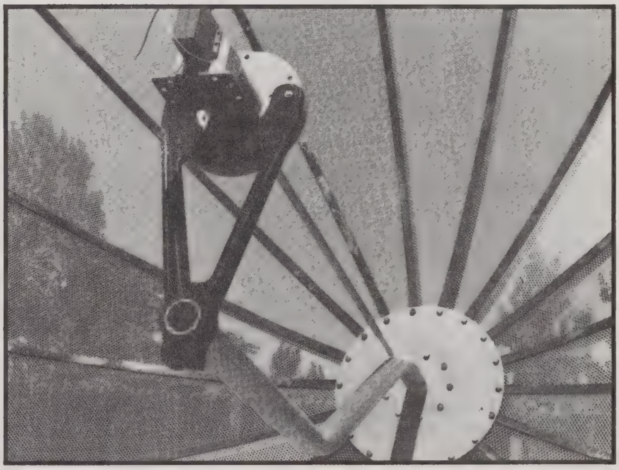


Figure 4-67. Using a Focal Finder. *This photo shows a focal finder inserted into the throat of a feedhorn. It points directly at the center of the antenna. If a tripod instead of a button hook feed support had been used, the focal finder telescoping arm would extend all the way to the dish center point of the antenna.*

Figure 4-68. Capping a Polarotor™. *It is essential that the plastic feedhorn cover which is transparent to microwaves be used to seal the throat of the Polarotor™ or any other polarizer. This prevents foreign objects from logging in its throat and interfering with reception of the satellite signals.*

E. INSTALLING ACTUATORS

Step number one in installing actuators is reading the instructions. No one knows better than the manufacturer how a poorly installed actuator can have problems. The instructions clearly spell out what mistakes to avoid as well as correct installation methods.

Mechanical Assembly

Once the dish is sitting on its pole, the actuator arm can be attached. Both pivot points should be affixed to the antenna mount with ball joints so it has some lateral movement and cannot bind. This is crucial since lateral forces on the inner tube can make it bend and seize up. These forces can also cause the internal O-ring seal which protects against water entry between the inner and outer tubes to wear out.

The arm should also be attached so it makes at least a 30 degree angle with the back of the dish at all points in its sweep. Having less of an angle makes the motor work harder since the arm has less leverage. Actuator arm lengths vary from 12 to 52 inches and should be chosen to give adequate leverage to easily move the dish. The larger and heavier the dish, the longer

the arm should be. And the arm should be as close as parallel to the plane of rotation as possible, also to minimize stress which could cause bending.

The collar on the outer arm should be set so that the antenna tracks past its most westerly target. This position is chosen because the actuator arm comes with the inner tube fully retracted.

Note that most actuator ball jacks can exert 1500 pounds or more of force. Acme arms can generate about 800 pounds of force. Make sure that the antenna has a full range of movement without coming into contact with any obstructions such as trees or fences. Also make sure that the actuator does not bind on any part of the mount or dish over its full range of movement, even past the preset electrically programmed east and west limits. Remember that enough cable should be left on the actuator (and the downconverter) so that the dish can move through the entire arc without pulling this cable so that a drip loop can be created.

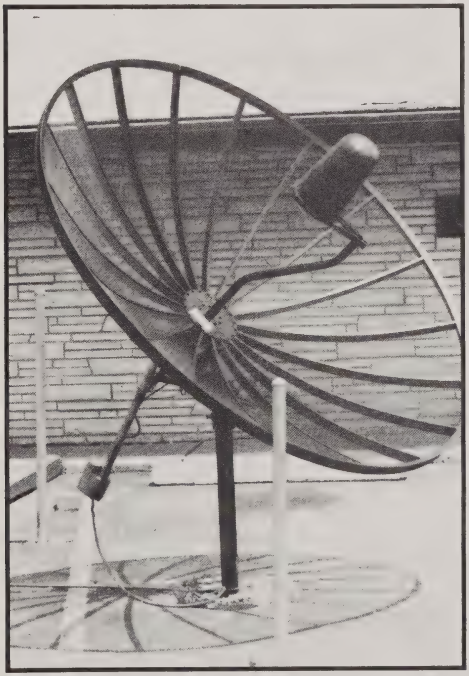


Figure 4-69. A Feedhorn/LNA Cover. *This 9 foot GeoTrac Antenna is well protected by a plastic feedhorn/LNA cover.*

Preventing Water Damage

Water is the chief enemy of actuators. If it manages to accumulate in the motor housing or in the gear box it can cause corrosion. More immediate damage results if this water freezes and seizes motors and gears.

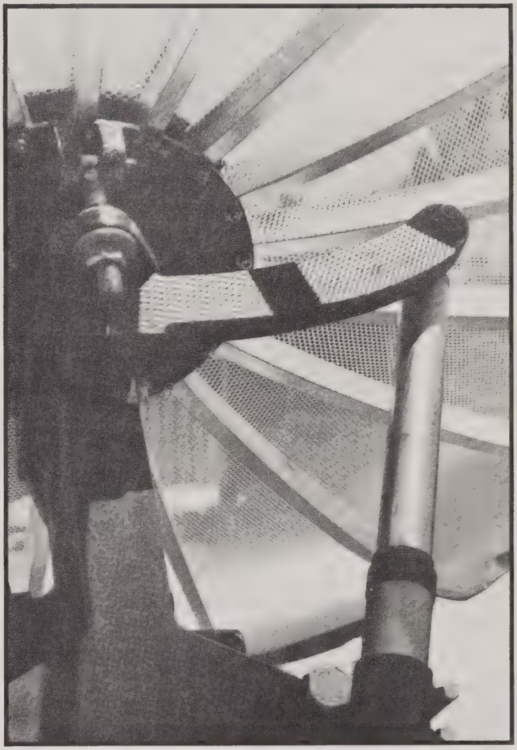


Figure 4-70. Mounting the Actuator Arm. *The angle between the actuator arm and the back surface of an antenna should be at least 30 degrees to give it the leverage necessary to transfer adequate force for dish movement. This arm must be mounted with the motor facing upwards to allow drainage and with ball joints at both points of attachment.*

Figure 4-71. An Unusual Use of Actuator Arms. *These actuator arms were used to lift this Prodelin dish so a declination bolt could be repaired without removing the antenna from its mount. Two crossed actuator arms could also be used to stabilize a fixed antenna.*

Actuators should be mounted so that the motor is facing upwards and the drain holes under the housing are facing down. If there are no drain holes, drill one or two 3/16 inch openings into the housing at the lowest point. This will allow water which enters by condensation to escape before it accumulates.

Another place where water can enter is the opening between the outer and inner sleeves. Most manufacturers provide a rubber fitting, called a shaft wipe, to protect this opening. Further protection can be realized with a neoprene accordion sleeve. This neoprene can absorb sunlight and allow any moisture buildup to evaporate. There should be a vent hole at both ends of this sleeve to allow water and air passage. So before any water accumulates it can evaporate and escape. If a rubber boot is used to cover the motor housing make sure that it also has large drain holes. If not, it can cause more damage than good.

Remember that actuators are the one piece of equipment that does the lionshare of the mechanical work. If not properly installed, a failure will probably result. Note that an estimated 75% of all service calls are for actuator-related problems! This is especially so in cold climates.

Wiring the Actuator

Most direct burial, multi-run cables provide the necessary five wire run needed to wire most actuators. This includes two #14 gauge wires carrying typically 36 VDC to power the motor. If the east button is pressed on the internal control box and the dish moves west, or vice versa, reversing these wires will correct the situation. Three shielded #20 gauge wires are used to send the counting pulses between the actuator sensors and in-door control box. Some systems do not require use of the ground wire connection but should. Note that these wires are shielded to prevent spurious voltage spikes from being mistaken for counting pulses when using control boxes that expect these pulses from Hall effect or Reed switch sensors.

It is important to use the seals provided to protect the points of cable entry against water instrusion. These should be secured tightly.

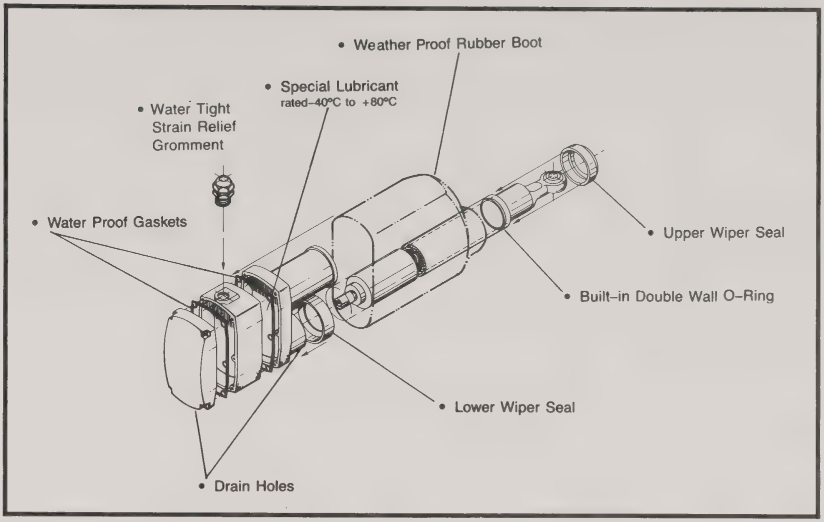


Figure 4-72. Waterproofing an Actuator Arm. *The schematic shows the points where an actuator arm can be protected against water. (Courtesy of Pro Brand International, Inc.).*

F. MOUNTING AND CONNECTING THE DOWNCONVERTER

Downconverters are mounted either at the focus of the dish behind the LNA, as is the case sometimes with block downconverters, or on the pole just below the dish in a weatherproof box. The choice of this mounting location depends upon the type of downconverter and its weight.

Most newer block downconverters are small and lightweight. They can be mounted directly onto the LNA with either a female/female N-connector coupling, which is best, or a short RG-214 pigtail, which cannot be kinked too sharply or its impedance will change and losses will result. In the latter case, the body of the downconverter can sometimes be secured onto the LNA with hose clamps or wire ties. These components should have a cover to protect against the elements.

Single and dual downconverters generally are larger in size. If too much weight is located at the feed structure like a bowling ball on a bamboo stick, winds or the tracking motion of the dish can cause unwanted vibration. If the downconverter is large and heavy it makes sense to attach it in a weatherproof box to the supporting pole. The connection between the downconverter and LNA is made with a RG-214 pigtail, generally about 8 to 10 feet in

length. The weatherproof box is strongly suggested to keep moisture away from the connectors leading into and out from the downconverter.

Single and dual downconverters when subjected to large temperature variations can cause drifting between satellite channels. In addition to the weatherproofing, some installers add insulating material to keep the unit cool in the summer and warmer in the winter. Leaving the electronics on all the time in the winter helps keep the downconverter warm and reduces drifting.

Single downconverters, if not shielded properly, can radiate interference back into a dish if mounted at its focus. This is because mixing frequencies are created in the satellite band 70 MHz higher or lower than the desired channel. These can potentially leak back into the dish and cause problems. It is recommended that single downconverters always be mounted on the supporting pole behind the antenna in a weatherproof box.

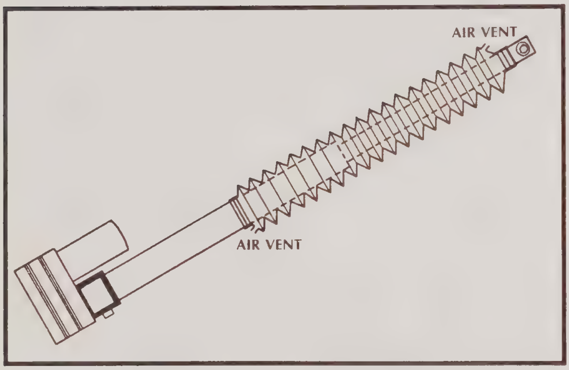


Figure 4-73. An Actuator Boot. *A neoprene actuator boot should have air vents at top and bottom and attach securely to both the inner and outer actuator arms.*

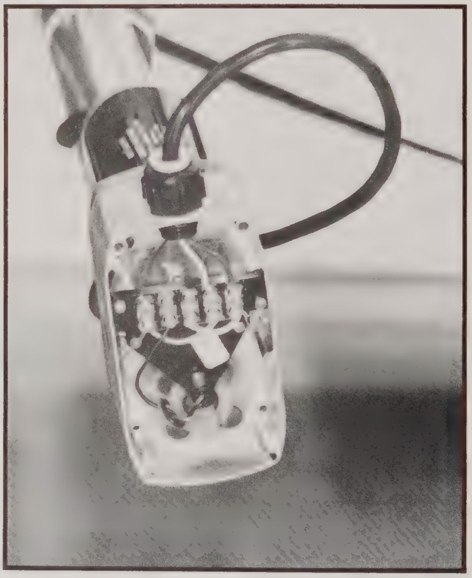


Figure 4-74. Wiring an Actuator. *Five wires are used to electrically connect this Houston Tracker III actuator motor to the in-doors control box. The two heavier gauge wires on the right are for motor power. If they are interchanged, the west and east movements will be reversed. The ground and two lighter gauge wires on the three left terminal strips are used for control voltages or pulses. Notice how the incoming cable is sealed against water entry by a tightly fitting plastic cap.*

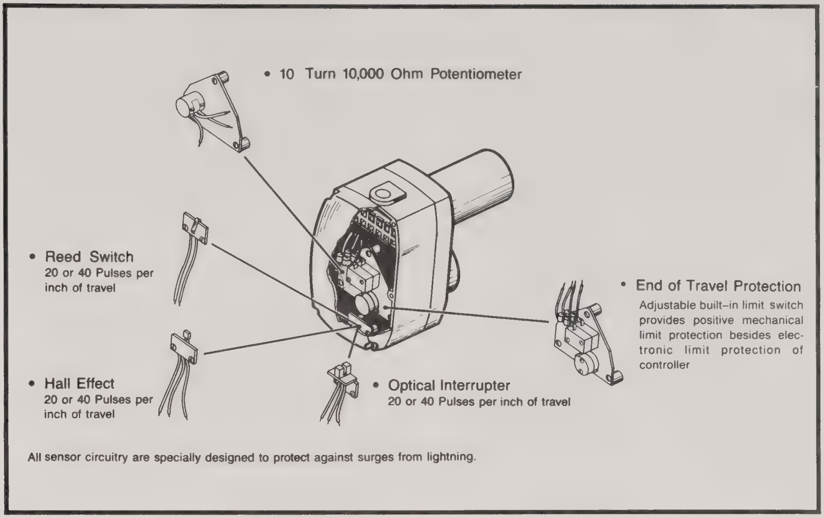


Figure 4-75. Actuator Sensor Positions. *Four types of sensors are used to monitor dish position. End of travel protection is also an important design feature. (Courtesy of Pro Brand International, Inc.).*

G. ELECTRICAL CONNECTIONS

Poor wiring techniques or improper connections can ruin an installation. A poorly gounded cable or a leaky connector may be all that it takes. Dealers should be familiar with those connectors that may be used and know how to correctly install them. Luckily, only a few types of connectors and cable have become standard in the satellite TV industry. So acquiring the necessary tools and knowledge is rather simple.

Connector Types and Techniques

The most familiar types of connectors encountered in satellite TV installations include N and F connectors, RCA or phono jacks, moly plugs and the solderless lug terminal. Each of these has certain uses and may require special tools to be properly installed.

N-Connectors

N-connectors are used to join LNAs and downconverters either directly via couplings or by attachment to the pigtail. At the high frequencies found in satellite TV it is very important to use a good-grade, silver-plated connector. Many distributors sell pre-made pigtails with N-connectors. When installing these connectors, solder-type attachments from the central conductor to the pin are preferable to the crimp-on variety.

Remember that incorrect installation of connectors can result in substantial signal loss, often much more than even the wrong choice of cable.

Figure 4-76. Mounting a Block Downconverter. *Many smaller block downconverters can be mounted directly onto the LNA output with a straight or a 90 degrees female-to-female N-connector coupling. If a short pigtail is used, it is important not to bend this coax too sharply as this could cause substantial loss of signal. In this particular installation, the Anderson 2010 block downconverter is mounted to a Chaparral Polaramp® by a 90 degree female-to-female N-connector.*

F-Connectors

F-connectors are the industry standard used for attaching coaxial leads to the downconverter, receiver and television sets. There are a variety of types used for both RG-6 and RG-59 coax. Some come with the crimp ring as a separate piece. It is imperative that these connectors be installed correctly.

F-connectors are attached by first stripping off about 3/4 inch of the outer insulation. Then the ground braid is folded back and trimmed to about 1/8 inch. This braid is next folded over the outside insulation past the 3/4 inch point. Then about 1/2 inch of the white center insulating jacket is removed from the inner wire. To makes sure that a good contact will be made use a knife and scrape the inner condutor wire clean. The crimp ring, if separate, is twisted on before the body of the connector. The connector should be twisted onto the coax so that the inner white dielectric jacket is flush with the inner shoulder of the F- connector. Finally, a crimp tool is used to bind the crimp ring onto the ground wire and outer sheath.

When installing a F-connector it is important that a crimp tool and not simply a pliers be used for the final step. The special tool compresses the connector onto the jacket equally on all sides. A pliers would distort the shape of the inner insulating jacket, alter the electrical characteristics of the cable and result in signal losses due to impedance mismatches.

Push-on F-fittings should be avoided. They do not provide as tight a RF connection as threaded connectors and can potentially let radiation leak into or out from the attachment point. They can also be more easily accidentally pulled off than the threaded type.

F-connectors can be joined together with couplers called F-81 barrels which have a female lead at either end. This is not recommended practice except when absolutely necessary as it causes some loss of signal at this juncture and makes an easier entry for moisture.

Phono Connectors or RCA Jacks

RCA jacks are often required for relaying audio and video outputs from receivers to stereo processors or to external modulators. They should never be used for higher frequency signals because they are not shielded as well as F-connectors. Most phono connectors need to be soldered onto a dual run wire or coax. A simple way to avoid the difficulty associated

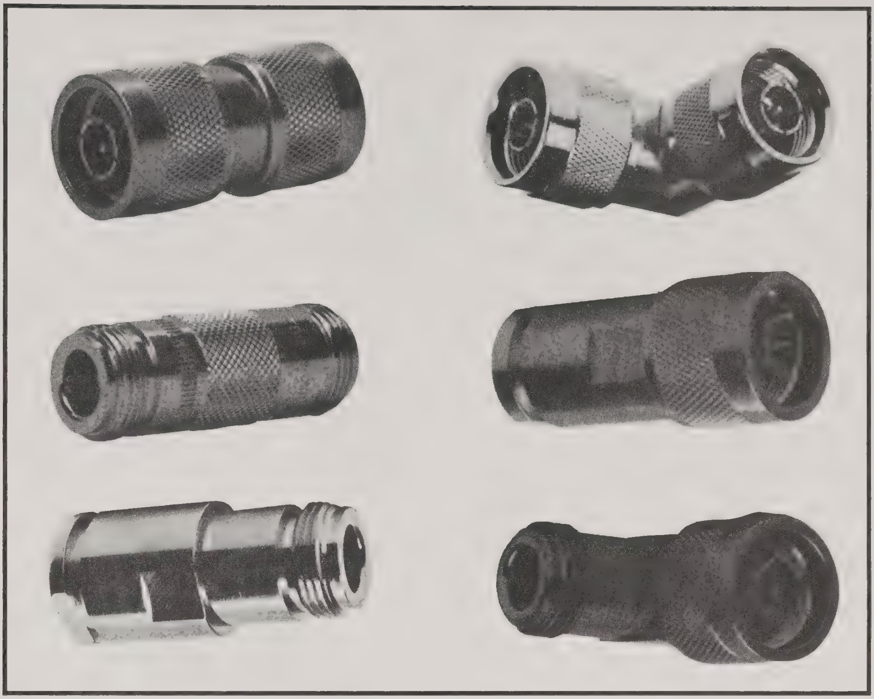


Figure 4-77. N-Connectors. *N-connectors are used to join RG-214 or similar cables and are rated for higher, C-band microwave frequencies. They are more difficult to properly install than F-connectors and are usually purchased already attached to this coax. The connectors in this diagram are in a clockwise direction from the upper left-hand corner: a female- to-female coupler; a 90 degree F/F coupler; a straight male to female coupler; a 90 degree M/F coupler; a female end connector; and a F/F coupler. (Courtesy of MACOM Industries).*

with soldering is to use phono-to-F-connector adaptors. Phono connector lines can be also purchased at audio or electrical supply stores in varying lengths having pre-attached connectors.

Nylon Block Plugs

Nylon block plugs (the Moly plug is a familiar variety) are occasionally encountered. These have internal pins which are inserted after the wires have been attached. These pins easily fit into the housing but are nearly impossible to remove without an extraction tool specially designed for this task.

The Solderless Lug

Solderless lugs are designed to be used with screw-on terminal strips as are often found on downconverters or receivers. The wire fits in one end and is either crimped down with a standard tool or soldered. Such lugs are recommended for attaching wires to screw-on terminals. Bare wires can fray and in time even short out to adjacent terminals. As a minimum, if lugs are not used, wires should be twisted and tinned before being screwed onto a terminal.

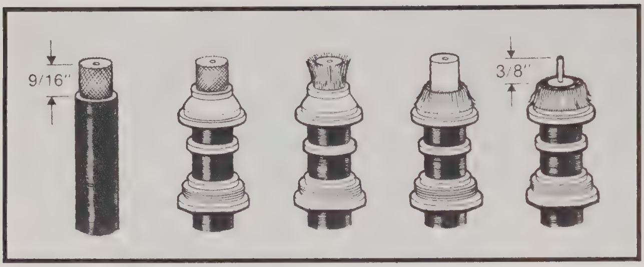


Figure 4-78. Installing N-Connectors. *This step-by- step procedure for installing N-connectors is shown here. Cut the outer insulating jacket back 9/16 inch. Then slide the pressure nut, rubber grommet, and the retaining ferrel onto the cable. Peel back the insulating braid. Remove 3/8 inch of dieletric from the inner conductor making certain not to score the wire. Solder the center pin onto the center conductor. Care should be taken not to use too much solder in the hole. Place the N-connector over the completed assembly and screw in the pressure nut. Be very careful not to turn the N-connector while tightening the rear pressure nut because the inner braid will break off. The center pin should not extend past the end of the connector.*

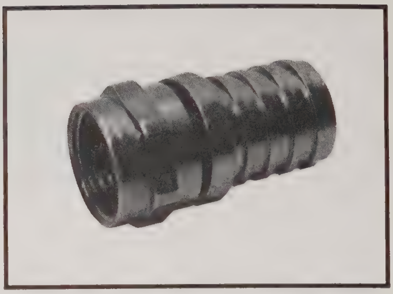


Figure 4-79. An F-Connector. *F-connectors are used with cables such as RG-59, RG-6 or RG-11 which are rated for frequencies below 1.5 MHz. (Photo Courtesy of MACOM Industries).*

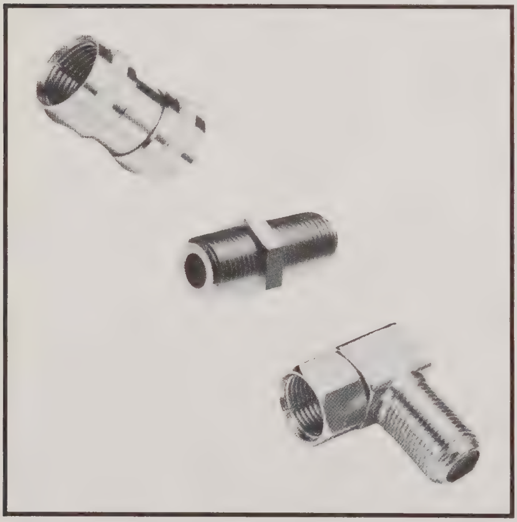


Figure 4-80. F-Connector Unions. *Three types of unions are shown here: a male-to-male splice (an F-81 barrel), a female-to-female splice (F-71) ; and a right angle female to male connector (F-40).*

1. **Cut cables to proper length.**
2. **Strip outer sheathing. (3/8")**
3. **Trim to expose core wire. (1/4")**
4. **Roll back metallic shield.**
5. **Push connector fully into cable.**
6. **Crimp ring where shown using appropriate tool.**

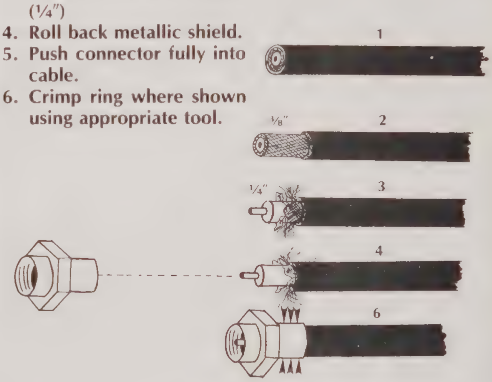


Figure 4-81. Installing F-Connectors. *This diagram shows a step-by-step method to install F-connectors.*

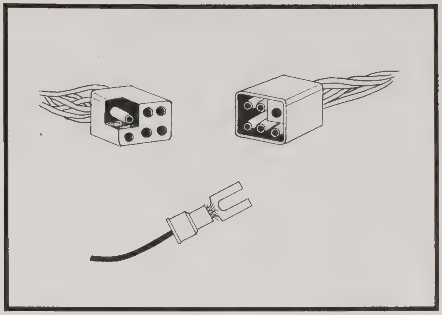


Figure 4-82. A Solderless Lug and a Moly Plug. *A wire is attached to a solderless lug by inserting and crimping its bare end onto the connector. A moly plug is used with a matching female receptacle for joining a multi-run wire together at a junction such as the rear panel of a receiver.*

Figure 4-83. Scotch Locks. *Three scotch locks are shown here. To make a connection, two unstripped wires are inserted and the button is crimped tightly down. The internal flooding compound then oozes out and seals the junction against water entry.*

Scotch Locks are another similar type of connector which is used for joining two wires together. These crimp-on connectors are filled with a flooding compound which is squeezed out during the crimping procedure. A good mechanical and well-protected electrical connection results. These connectors are ideal for use in attaching polarizer wires.

Additional Pointers on Installing Connectors

When stripping insulation or ground braid off from cables and wires, be careful not to score the internal conductor. This would weaken it and could cause breaking at some later time. Also, be careful, especially when peeling the outer insulation off coaxial cables, that the tiny pieces of wire do not fall into a vent in the actuator control or receiver. Such wires could short an internal component and burn out the unit.

As a general rule, never splice cables. However, some cables can be extended with the appropriate adaptors joined to fittings on both pieces of cable. If the point of union is exposed to weather, use both coaxial sealant and a rubber boot or shrink-fit tubing.

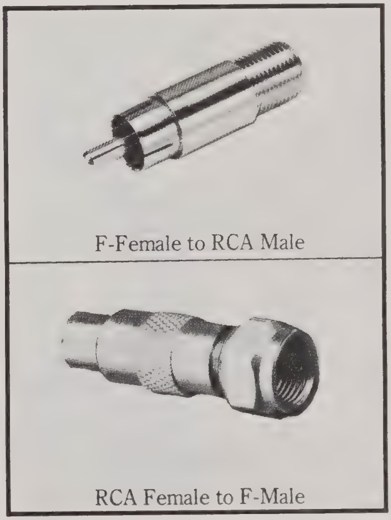


Figure 4-84. Phono to F-Connector Adaptors. *Two types of phono to F-connectors adaptors are pictured here, a female jack to a male F-connector and a female jack to a female F-connector.*

Adaptors are also available to join different types of connectors. For example, an RCA to F-connector adaptor has a male F-fitting at one end and a standard phono jack at the other. This particular adaptor often is needed when attaching stereo processors or external modulators. It is much easier making a cable with F-fittings at either end and using an adaptor than installing a phono jack at one end and a F-connector at the other.

The Final Wiring

The wiring sequence to be followed depends upon how the final adjustments of dish position will be made. If a test setup at the antenna is first used, temporary wiring is required. If the dish will be tweaked using walkie-talkies to communicate from the in-door receiver to a crew member at the dish, the final wiring is completed without an intermediate step.

If the dish will be adjusted from in-doors, all out-door electrical connections may be made before the dish is raised into position to track the arc. The electronics at the focus are more easily reached with the antenna angled down. If the downconverter is not attached to the LNA, a pigtail must join these two. The input to the downconverter often consists of a F-connector and two wires to provide power. However, block downconversion receivers are now designed so both the DC power and the IF signal are carried on the same piece of coax. In this case, only one input connection to the downconverter is required.

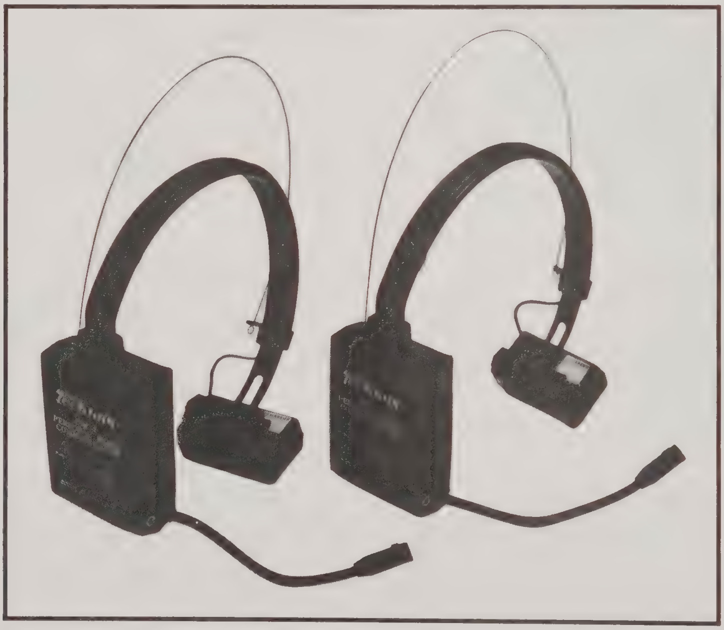


Figure 4-85. Walkie-Talkies. *When two people are doing the final tweaking on a satellite system where the receiver and TV is in-doors, walkie-talkies are indespensible.*

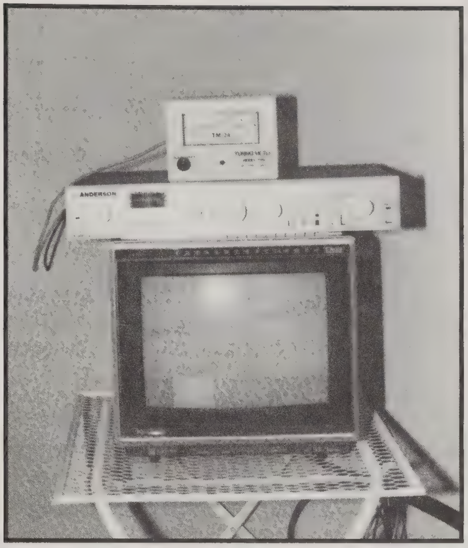


Figure 4-86. Tweaking with Test Equipment at the Antenna. *A receiver and television can be connected out-doors next to the dish so both the signal strength meter and picture can be monitored while tweaking the antenna. A signal strength meter which is more sensitive than those found in most satellite receivers or another specially designed testing component is recommended in this situation.*

Next, three leads are attached to the polarity selection device. If possible, Scotch locks should be used. If not, they should be twisted tightly together, soldered and then covered with wire nuts or other types of crimp-on connectors. These are then covered with "shrink spaghetti" which, like shrink tubing, contracts when heated by a small flame or hair dryer. Finally, the five wire actuator lead is hooked up and double check for proper connection.

The video receiver has an F-connector input for the IF signal, there is sometimes a separate terminal strip for downconverter/LNA and polarity power. Actuator wires are attached to eitehr the actuator control box or to those receivers with built-in actuators. In those cases where a unit such as the Houston Tracker IV or V which controls the receiver functions is used, th polarity selection leads are wired into the actuator.

Finally, every connector should be examined carefully prior to mating to ensure that the center pin has not been broken off and is centered and properly extended. There will be no electrical contact if the pin does not extent far enough and damage may occur if the pin is not centered or extended too far. Note that LNAs and downconverters damaged by off-center pins cannot be repaired under warrantee. It can also very difficult to locate a poor connector once an installation is completed.

Protection Against Power Surges and Lightning

A direct lightning hit is a rare occurence and can not only destroy the electronics in a satellite system but can also set a house on fire. However, most hits are indirect and cause power surges. The 60-cycle power provided to many rural regions is often not very "clean" and produces similar but much smaller voltage transients which can cause a receiver or actuator control to lose memory. It is better to take precautions than to make a time-consuming service call. Note that most receiver warantees do not cover "abnormal conditions of operation" such as being hit by lightning or other acts of God.

Ground Rods

Ground rods are usually long narrow poles of copper-clad steel which are driven into the ground to provide an escape route for lightning. An 8-foot rod will usually suffice. Their effectiveness depends upon the ability of the soil to pass current, the soil resistance, and details of their connection to the dish and mount.

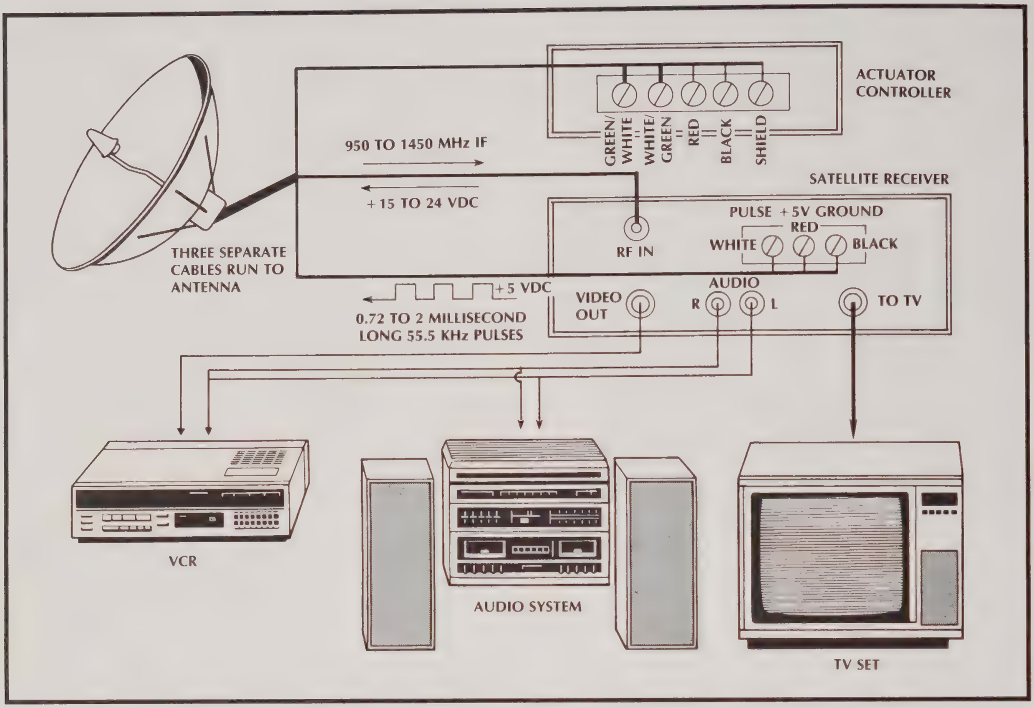


Figure 4-87. Typical Earth Station Wiring. *A satellite receiver can be connected to a complete audio/video entertainment center. This diagram shows how a block downconversion receiver is wired. It sends both 15 to 24 volts DC to the downconverter and LNA and receives the RF signal on a single coaxial cable. A single or dual conversion receiver would require an extra two-wire cable for relaying power. The receiver is also connected by three wires to the polarizer. These send 5 volt DC pulses. every 18 milliseconds (which equals a frequency of 55.5 KHz hence the name 555 timer chip). The servo motor probe position is controlled by the pulse width which varies from 0.72 to 2 milliseconds. The in-doors actuator transmits 6 VDV to and receives pulses from a sensor on three wires and sends typically 36 volts DC via two "motor" wires to control antenna position. This particular receiver has a built-in stereo processor and controls the home audio system via audio output terminals. Otherwise the baseband output would be used to drive a stereo processor. The VCR can be connected to either the TV or video output ports.*

Most soils have adequately low resistance so that a good ground connection will effectively shunt voltage transients caused by nearby lightening strikes. Soils which have little clay or loam but are mainly rocky may need to be treated with materials like rock salt, copper sulphate or magnesium sulphate to increase their ability to pass current.

A ground rod should be driven about a foot or so away from the supporting pole foundation. A minimum 1/4 inch copper or 3/8 inch diameter aluminum wire is bolted onto the ground pole. A tight clamp, often provided with the rod is used for making contact at the top end. This wire should follow a smooth curve; any sharp bends will impede current flow. It is

interesting to realize that, for the same reason, if knots are tied in regular power cords, voltage transients will have a harder time finding their way into electronic components.

An effective method to plant a grounding rod is to use a pipe with a cap on one end as a driving tool. If the soil is difficult to penetrate, water can be added to the hole as the rod is driven. The top of the rod should be planted at least six inches below the ground for best results. This will also protect the customer's lawnmover as well as the customer from damage. A driver sleeve is also available for use with a standard jackhammer to plant the rod. This is a must tool in many cases.

Probably the best alternative to using a ground rod is to run a heavy gauge wire, #8 or larger, from the pole or dish to the location where the house electrical circuits are grounded. This should effectively shunt any excess currents to ground. Note that any paint should be removed from these points of contact prior to attaching the ground strap so that a good electrical contact is made.

Surge Protectors

Surge protectors can also be used to protect electronics from small to large voltage spikes. There are many varieties available ranging from simple units which plug into a power line to more expensive ones requiring the installation expertise of an experienced electrician. All earth station components should also be well grounded together for additional protection. Note that some brands of LNAs use "grounded probes" which can withstand short duration power surges of up to 1000 amps.

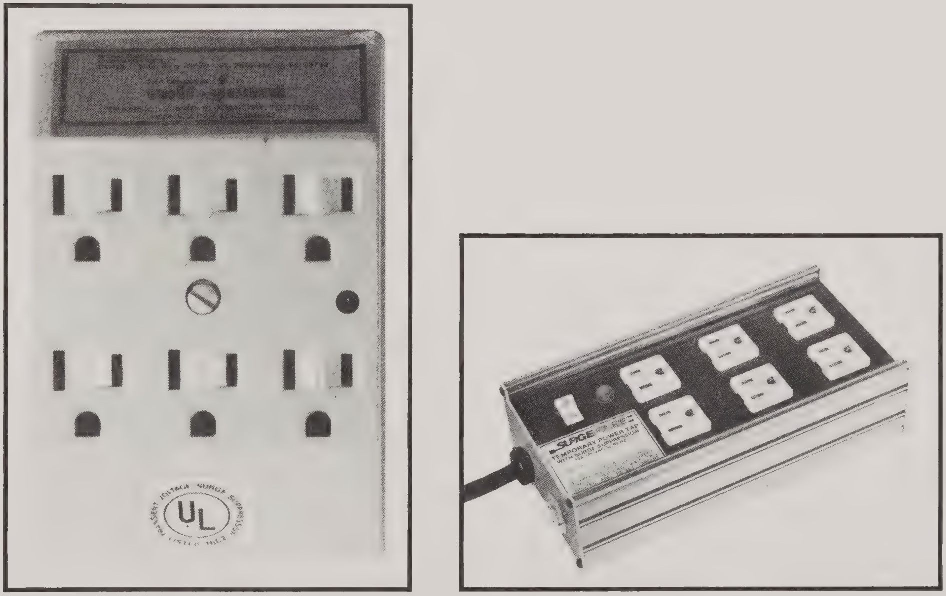


Figure 4-88. Surge Protectors. *The Volt Guard surge protector will self-destruct if an excessively strong voltage transient appears on the power line. The Surge Free protector has an internal power breaker which can be reset. It also features an off/on switch. (Courtesy of Volt Guard, Inc. and Surge Free).*

H. ALIGNING THE DISH

The next step is the exciting one, actually getting television from the satellites. Either one of two methods can be used to accomplish this. The final wiring can be completed and a set of walkie-talkies can be used to communicate between one person at the receiver/actuator and another at the dish. Or a complete test setup can be hooked up at the dish. The second method is recommended when weather permits. There is less possibility for miscommunication and, if necessary, just one person can complete the installation.

The test setup should consist of a receiver, a signal strength meter, an actuator, and a small television or monitor. An alternative to moving the dish during tweaking with an actuator is to remove the motor and its housing from the actuator arm and then to use a small hand crank to scan between satellites. Also, in many cases, a signal strength meter is built into the video receiver. This can be adquate but a more accurate instrument can be used by a professional installer to give even better results (see below for more details). If a small monitor or TV is a standard part of an installer's test equipment, a customer's set will not have to be disconnected and lugged out to the site. Using a familiar TV eliminates the possibility that his or her TV is malfunctioning. Also, have a supply of 75 to 300 ohms transformers on hand. These will be necessary if the customer's TV is an older model and does not have F-connector attachments.

The tweaking procedure should be conducted using the receiver and actuator which is being permanently installed. But if difficulties with any electronic component arises, have a spare receiver and actuator which is known to be working on hand for use as a substitute.

Ways to Test Components Before Setting Angles

By far the easiest method to test if equipment is working is to check out each electronic component on a working dish back at the shop. Taking the necessary half hour of time to do so in a familiar environment can eliminate many installation headaches. It is strongly recommended.

Alternatively a portable signal simulator such as the GBS-1600 (see Chapter VII) which broadcasts a C-band color bar pattern can be used at the test site. It has a small antenna which when pointed at the dish should cause color bars to be seen on the monitor. If not, a series of simple troubleshooting techniques can be used with this signal simulator to isolate the defective component or connection (as detailed in Chapter VII). If color bars are seen, the dish can be aimed at the arc of satellites with confidence.

If the first two methods are not used, another type of pre-tweaking testing can also be done to allow an installer to be fairly certain that the new equipment is working as expected. First be sure that the TV is tuned to the same channel as the modulator (usually channels 3 or 4). If necessary, the TV can be checked out before this by viewing a local off-air channel. Now be sure that a coaxial cable is attached between the TV set VHF input and the RF output on the receiver. Set the audio mode selection to the mono position if there is a choice between this and stereo.

If the cable from the downconverter to the receiver input is disconnected and if the re-

ceiver and TV are on, the screen should be black or blank white. If not, the receiver has a short or the cable between them is broken. Always be careful to turn the power off and unplug the receiver before disconnecting or connecting any components since damage can be caused by shorting a center lead to ground.

Next, the downconverter should be connected and the cable between the LNA and downconverter disconnected. The television should have a little noise and audio hiss. If not, something is amiss with the downconverter. Finally, hook up the LNA. The screen should be covered with white noise and a loud hiss should be heard. If not, the LNA is either defective or is not getting power from the receiver. Note some downconverters require that a jumper be connected so that the LNA receives power.

Another option is to use a voltmeter to check for the appropriate 15 to 24 DC volts at the receiver output and downconverter input. If the proper reading is indicated, the components are probably good. Next check that the voltage going to the LNA is adequate. To do so will require using a 2-way, DC-passive power splitter which allows current to pass in both directions. If power is not getting to the LNA, the downconverter may be bad. These procedures are outlined in much more detail in Chapter VII.

Aiming the Dish at the Satellites

Three adjustments are required on most dishes to allow the arc of satellites to be tracked: north/south heading; declination offset angle; and polar axis angle. Once these angles have been set in one or two installations, the procedure will become easy. It is also usually simpler to set these parameters if the dish is at the center of the arc and is facing south. This can be accomplished by turning on only the actuator and moving it to this position with the east or west buttons or by using a hand crank or slide arm bar.

North/South Orientation

A polar mount must have its axis aligned with the north/south axis of the earth in order to be able to detect all satellites in the viewable arc. This is easily understood by visualizing an antenna at the equator. Only if it rotates in an axis aligned with the center of the earth, will it correctly scan the circle of satellites in the sky above.

Most dishes have a flat plane on the mount which can be used as a sighting reference. A hand-held compass with cross-hairs is the most effective type for lining up with this plane. Remember, that a correction for magnetic variation is necessary. West of the line of zero variation, the agonic line, rotate the dish east of magnetic south by an amount equal to the variation. East of this line, rotate the dish west to correct for variation.

The Polar Axis Angle

The polar axis angle is set equal to the site latitude. This targets the dish straight out into space along a plane parallel to the equatorial plane (see Figures 2-20 and 2-21). Most dishes have one or two long threaded rods which are used to adjust polar axis angle. An inclinometer resting on the axis bar or back part of the mount is used to set this angle.

Declination Offset Angle

The declination offset adjustment lowers the antenna's sight from a plane parallel to the equatorial to the arc of satellites. The declination angle is greater in more northerly locations. The chart below shows how declination varies with latitude.

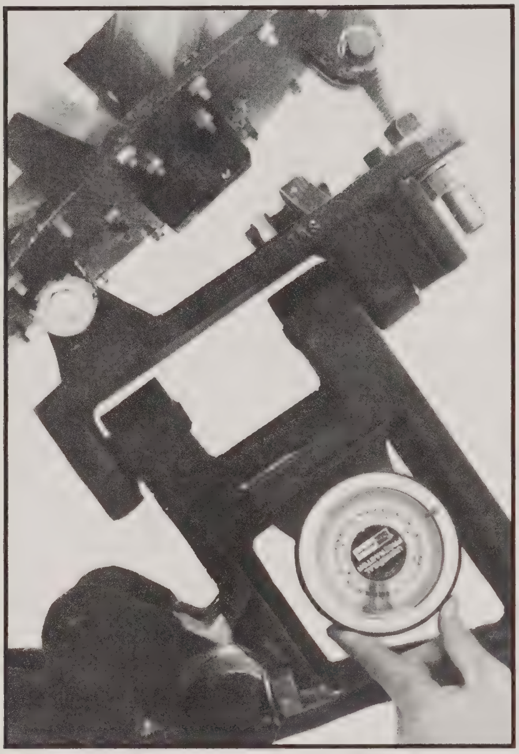


Figure 4-89. Setting the Polar Axis Angle. *The polar axis angle is set equal to the site latitude by placing an inclinometer on the axis bar, the rear surface of the mount.*

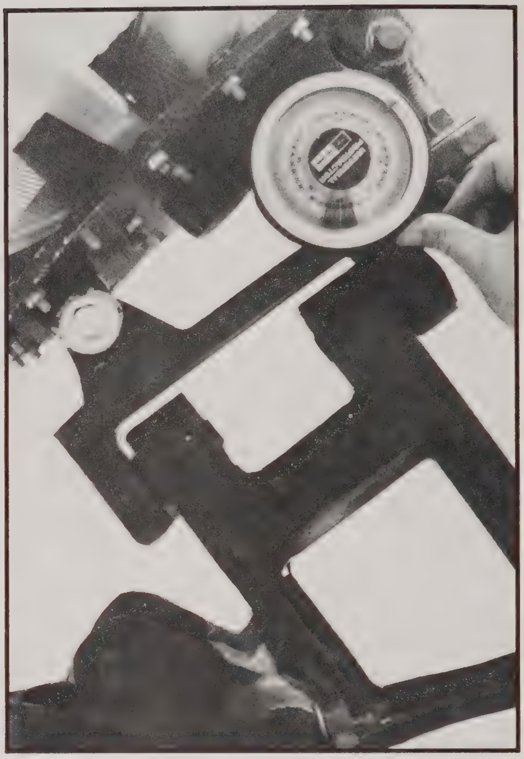


Figure 4-90. Setting the Declination Offset Angle. *The declination offset angle is set by placing an inclinometer on a flat, rear surface of the dish and adjusting until it reads the sum of the declination plus site latitude angles.*

The declination offset angle is measured with an inclinometer. The difference between two readings, one on the main part of the mount, the axis bar, and one on a flat spot on the back of the dish, should equal the declination offset angle. The easiest way to set the declination offset angle is with an inclinometer placed on a back surface which is parallel with the face of the dish. This reading should be set equal to the sum of the site latitude plus the offset angle. For example, in Denver the latitude is 40 degrees so the polar axis angle is set equal to this value. The declination offset angle is 6.2 degrees so the dish should be set at a 46.2 degree elevation. Similarly, at a latitude of 35 degrees, the declination offset angle is 5.7 degrees, so the final elevation is 40.7 degrees (see Figure 2-21).

Most antennas have continuously adjustable declination offset angles set by moving the assembly on one or two all-thread bolts. Some dishes have a built-in declination offset, usually approximately 6 degrees, so no adjustment is necessary or possible. Other mounts have just three offset adjustment positions selected by using one of three bolt holes. Other types have an offset angle scale actually built-into the mount which indicates the distance to be set. Note that once the declination offset adjustment

is properly made, it most often does not need further adjustment.

Powering On and Aligning Onto the Arc

The time has come to watch satellite television. Check all connections and leads one final time before turning the equipment on. In rare cases, a satellite will happen to be targeted by the initial adjustments and clear pictures will immediately appear on the TV. Congratulations! However, if all angles have been carefully set, it is not at all unusual to be able to locate a satellite without any further adjustments by simply scanning across the arc. Note that when using a very large antenna with a very narrow beamwidth it is rare that further tweaking is unnecessary because the dish has to aimed so accurately (see Chapter VI for more details).

TABLE 4-9. POLAR MOUNT POLAR AXIS AND DECLINATION ANGLES

Site Latitude	Polar Axis	Declination
26	26	4.4
27	27	4.6
28	28	4.7
29	29	4.9
30	30	5.0
31	31	5.2
32	32	5.3
33	33	5.4
34	34	5.5
35	35	5.7
36	36	5.8
37	37	6.0
38	38	6.1
39	39	6.2
40	40	6.3
41	41	6.4
42	42	6.5
43	43	6.6
44	44	6.7
45	45	6.8
46	46	6.9
47	47	7.0
48	48	7.1
49	49	7.2
50	50	7.3
52	52	7.5
54	54	7.6
56	56	7.8
58	58	7.9
60	60	8.1
62	62	8.2
64	64	8.3

Often, a good starting point is to target a satellite which has most of its transponders active. For example, Galaxy I and Satcom III have almost all 24 transponders in use. Another option is to begin with an active satellite located near due south in any particular location. For example, in Denver, Anik D1 is only half a degree off due south. A dish can be fairly easily aligned with this satellite. Note that while a dish is being aligned onto the arc, it is necessary to have either a TV guide or an excellent memory so those transponders which are active during the installation can be identified.

Many receivers have a scan control on their tuner which causes all channels to appear on the screen in rapid succession. This is a very useful feature for locating active transponders on satellites. If the dish is slowly moved across the arc, all channels on each satellite targeted will flash across the screen. As soon as anything other than white noise appears, stop moving the dish, take the receiver off scan and try to find a picture by tuning through all 24 channels. All that is needed to start the tweaking process is even a semblance of a picture. If the receiver does not have a scan feature, check the TV guide and pick an active channel on one of the satellites which is broadcasting during the installation. Then aim the dish as closely as possible to this satellite and begin the hunt.

Note that if the receiver signal strength meter is "maxed out," it can ususally be adjusted to a lower sensitivity by either a front panel button or a back panel or internal potentiometer setting. These adjustments may not be enough to

Figure 4-91. Variation of Declination Offset Angle. *The declination offset angle for any locale in most of North American can be read from this map.*

Figure 4-92. Latitude and Longitude Map. *This map can be used to pin-point the latitude and longitude of any location in those parts of Canada, Mexico and the United States illustrated.*

lower the meter sensitivity when testing at the dish since cable runs are very short. Most meters built into receivers are set to compensate for losses in the typical 100-foot run of coaxial cable. Inserting 100 feet of cable may set the meter back down into the readable range. Another reason why the meter can peg is terrestrial interference. But this possibility should have been eliminated during the site check. If not, have notch and bandpass filters on hand.

Once a picture has been detected, try to improve it by moving the dish ever so slightly east and west and by adjusting the polarity and video fine tune. (Make sure that a side lobe is not being targeted by mistake.). Note that during this procedure it is usually best to turn the receiver AFC off. Also, make sure that the probe on the polarizer is moving when the skew adjustment is rotated or when channels are changed from even to odd. Next, push the dish up and down from the front bottom rim. Take care not to bend the dish. If the picture improves, adjust the elevation in that direction until the best picture is received or the signal strength meter has the highest possible reading.

Then try to target a second satellite. Either make sure that the receiver is set on an active transponder on the satellite or use the scan setting. It will probably be necessary to readjust the skew and video fine tune as well as the polar axis angle once a picture is seen. If pictures are excessively sparklie the feed may need adjusting, there may be a loose connector or TI may be present (see Chapter VII for more much more detail).

Next go to a satellite near one end of the arc. When a picture is detected, note the movement needed in the polar axis to improve pictures. If it was necessary to raise or lower the dish, the north/south axis needs some minor correction. For example, if pictures were peaked on Satcom I but the dish needed to be lowered when swept to Satcom II, then the dish and mount have to be rotated west. Note that these north/south readjustments should be small movements - on the order of 1/16 of an inch. These movements can most easily be accomplished by pushing on the outer rim of the antenna where leverage is greatest. Pushing from the mount will cause jerky, unpredictable movements. Do not overshoot the adjustment so much that the process has to be started over from the beginning. Also, make sure that the bolts are only slightly loosened to allow this small north/south movement. A dish is often quite heavy and should not have the opportunity to pull the mount forward on its supporting pole. If adjustments are made with the mount slightly tilted, when the bolts are tightened, the mount will pull back and the dish will be pulled slightly off target. Be aware that this can happen and therefore in most cases a slight lowering of elevation will correct the error. And do not make more than one adjustment at a time; it can only confuse.

After the antenna is tracking the arc reasonably well fine tuning should begin. Accurate readings are now taken from the signal strength meter. It is important during these steps that the scale chosen on the meter be left unchanged so that comparisons are possible between these readings before and after changing any settings. For example, assume that the meter reads 6.23 on transponder 20, Satcom I. Then the antenna is moved to Satcom II and fine adjustments in north/south position and polar offset angle are made. When the dish is returned to the same channel on Satcom I, the new reading should be compared with the old one. After readjusting to obtain the best signal, this reading should at least be as much as the old one. For the same reason, it is also important to keep the skew adjustment knob unchanged. This is possible if transponders on satellites having the same polarity format are being compared. For example, Satcom I and II, both RCA satellites, are at opposite ends of the arc and have the same polarity format. Or Comstar D4 (which is known as Telstar 303 as of late summer 1985) and Telstar 302 have similar formats. Note that transponder 20 is active on Satcom I, Satcom III, Comstar D4, Telstar 302 and Satcom II. Since these satellites span the whole arc and also all have the same polarization format, they are useful for tweaking comparison purposes.

TABLE 4-10.
ANTENNA TWEAKING PROCEDURE

1. Carefully check that the feed system is centered and located at the correct focal distance. Remember that it is important that the feed be peaked before tracking is started.

2. Set the two necessary angles, polar axis angle and declination offset, and align the dish polar axis in a north/south direction as well as possible. Remember that it is easiest to adjust the polar axis and declination offset angles on a satellite high in the arc, i.e. near due south, and to adjust the north/south orientation during the following step on a satellite lowest or at either ends of the arc. Remember, elevation on a high satellite; north/south on a low satellite.

3. Check all connections and turn the power on.

4. Aim the dish at a preset position or slowly track across the arc to find even the faintest picture.

5. Once a picture has been detected, move the dish slightly east and west and adjust the polarity and video fine tune on the receiver to get the best possible reception. Then make any adjustments necessary in the polar axis angle to further improve reception.

6. Move to another satellite, preferably at the far end of the arc, and attempt to tune in a second channel. During this and procedure number 3, having a receiver with a scan setting is very useful. If not, set the receiver channel selector on a channel known to be active on the satellite being targeted. If a channel cannot be located on this satellite, move to another one closer to the first successful target. If three or four satellites in a cluster but none others can be found, the north/south alignment is probably substantially off and needs correction.

7. Tune in this second satellite as well as possible with the video and skew fine controls and east/west scanning.

8. Next, determine if the dish has to be pushed up or down to improve reception. If neither, move to another satellite at the other end of the arc and try again. In those rare cases when all satellites are targeted accurately, jump to step number 10. If adjustment is necessary, consult the tracking Figure 4-93 to determine which direction to rotate the north/south axis.

9. Make a small movement of this axis in the correct direction.

10. Return to the original satellite and repeat this procedure to further zero in on the arc. It makes sense to do this for one satellite at the far eastern and far western end as well as one in the center of the arc for best results.

11. Next chose three satellites at the middle and both ends of the arc which have the same polarity format and a common active transponder. Adjust the skew and video fine tune controls one last time to maximize the signal strength meter reading on one satellite. Do not touch these controls until this procedure is completed. Repeat steps 4 through 9 again to get maximum readings on all three satellites. At this point, some adjustment to the declination offset angle could possibly be necessary.

12. As a final test, tune to the weakest transponders in the arc such as 4, 6 and 8 on Satcom III. If excellent pictures can be obtained on these as well as on satellites all across the arc, all adjustments are correct and the arc is well targeted.

13. Tighten all bolts carefully watching to be sure that the signal strength meter maintains its maximum readings. Some small readjustments to elevation may be necessary if the mount pulls up or down on the pole when being tightened.

When the dish is accurately tracking, the maximum signal strength readings should be obtained on all the satellites. Generally this can be accomplished by adjusting just the north/south position and the polar axis angle. However, the declination offset angle will occasionally need some small readjustment especially for satellites on both ends of the arc.

For further clarity this proceedure is outlined step by step in Table 4-10. Read and understand this table. If followed carefully accurate tracking can be easily accomplished.

Six common tracking problems are illustrated here. The best way to visualize these is to picture the arc of satellites as one circle and the tracking movement of the dish as another. Both of these circles must be aligned for perfect tracking. It really is that simple. Note that none of these procedures will work if the pole is not perfectly plumb or if the mount is not sitting vertically on the pole. If problems are encountered, check these mechanical settings. Also, make sure that the dish does not have the opportunity to be driven into a table, toolbox or even an installer's vehicle while it is being scanned across the arc.

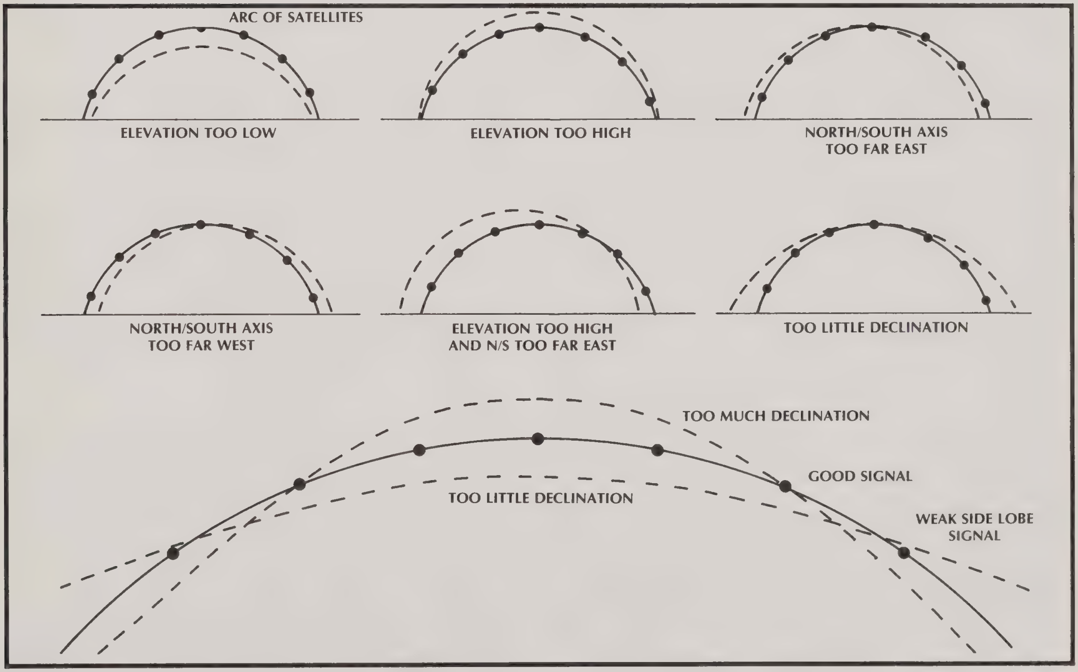


Figure 4-93. Common Antenna Tracking Problems. *Most tracking problems are associated with an incorrect north/south orientation. However, if the declination angle has not been adjusted correctly, tracking will also be incorrect. Lining up an antenna with the geosynchronous arc of satellites is simply a matter of lining up two half circles, that in which the satellites are located and that scanned by the polar mount.*

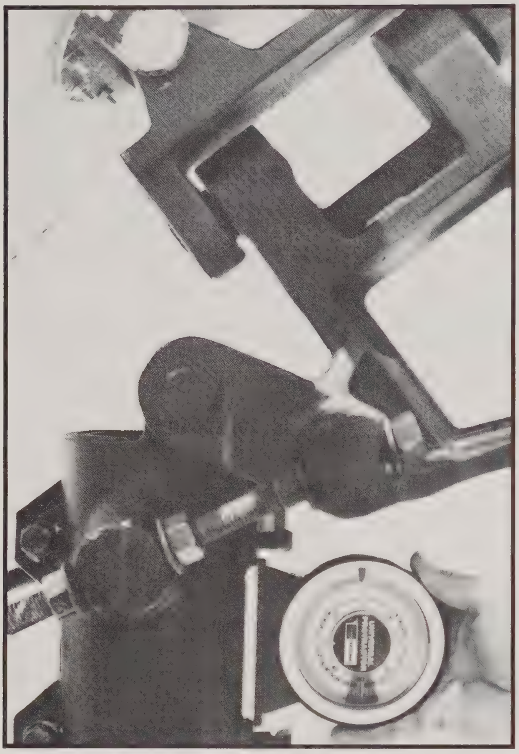


Figure 4-94. Rechecking the Plumb Line of the Mount. *Tracking errors can be occasionally caused by unexpected occurances. For example, tracking will be off if the pole is perfectly level but the mount does not plumb. This could occur if the top of the pole had not been cut straight.*

This tweaking process is completed by making the necessary adjustments at both ends of the arc a few times. Satellites at the center of the arc should also be targeted to check if all the fine adjustments are correct. Tighten all bolts and nuts and then recheck to make sure that doing so has not slightly altered the alignment.

During this proceedure, familiarity with what channels are on what satellites is invaluable. By far the easiest way to learn this information is by having experience with a working satellite TV system. It becomes clear that, for example, if a station having French language is located, the satellite is Anik D1. Become familiar with those satellites and transponders having test patterns with the satellite name and transponder number. These are invaluable in the search.

Tweaking for that Last Decibel

The dish can be aimed by observing the television screen and then by adjusting for the best picture on a sample of the weakest transponders across the arc. This can be a reasonably good method. But even more accurate aiming and therefore better use of the available equipment can usually be achieved with more sensitive measuring tools.

The simplest strategy is first to target the arc as well as possible as outlined in Table 4-10. using a monitor or television. Then signal strength can be monitored with a more sensitive measuring device so that even finer adjustments can be made to the feed position, north/south orientation, polar axis angle and declination offset angle, if necessary. Another alternative is to use such a fine tuning instrument to aim at the satellite belt along with the television set from the onset. The choice between these two strategies is a matter of taste. Note that signal strength meters which are built into receivers are usually relatively crude instruments not really suited to tweaking out that last decibel or two.

Where is this signal power measured? Since instruments for measuring microwave power levels are very expensive, taking a sample at the LNA output or downconverter input is unrealistic. But devices are available to measure the strength after signals have been downconverted to an IF range. The first to be introduced was an adaptor called an "RF head" or a carrier level detector which plugged into an inexpensive voltmeter and gave this tool the capability of reading 70 MHz signals. (The model "82RF" from John Fluke Manufacturing was the pacesetter). Note that neither a voltmeter,

which is designed to detect much lower frequency signals, or a field strength meter, which monitors AM signals on a cable TV system, can be used for 70 MHz signals. And the RF head is not capable of measuring signals having frequencies much in excess of 70 MHz. This rules out its use with block downconversion receivers whose downconverters relay intermediate frequencies in excess of 450 MHz.

Three other instruments to monitor signal power levels at the downconverter output are now available. The "Tweaker I" and "Tweaker II" have scales with adjustable sensitivity from 0 to - 64 dbm to read power. The "Squawker" has a variable sensitivity digital scale to handle -7 to -48 dbm powers but also has an audible tone output which increases in frequency as signal strengths rise. The digital scale allows greater accuracy in reading powers than an analog scale. The "Sat-Finder" is an RF head and requires an accompanying multimeter for operation. Unlike the first two, it is not battery operated but requires connection to the DC power line. The Squawker and the Tweaker II are also both capable of being used with signals from block downconversion receivers which range up to 1450 MHz in frequency.

Note that all these instruments must be protected from being zapped by downconverter/LNA DC power. A directional coupler which passes DC between two ports but isolates the third test port should be used in those lines also carrying DC power. The Tweaker has a built-in coupler so the downconverter output can be connected via a short jumper cable into one port of the test device while the cable from the receiver is connected into the other port. DC protection is provided internally.

Final Feedhorn Centering Adjustments

Feedhorn centering adjustments should be made before the dish is tracked. But, at this point the feedhorn can be adjusted one last time in an attempt to further improve television reception. If the feedhorn is precisely at the "phase center" where all the signals are focused, the picture quality will be at its best. Moving this assembly away from its correct position will degrade picture quality by lowering gain and increasing side lobe power.

Moving the feed assembly in towards the dish will decrease the signal power relative to side lobe power. This will show up as a decrease in signal strength. Moving away from the dish will also decrease the ratio of signal to side lobe power. However, the signal strength will usually increase as more noise from the surrounding ground is detected. If both the TV picture and signal strength meter are carefully monitored at the same time, knowing these effects, the feedhorn can be located precisely at the phase center. The payoff in improved picture quality will be more than worth the trouble.

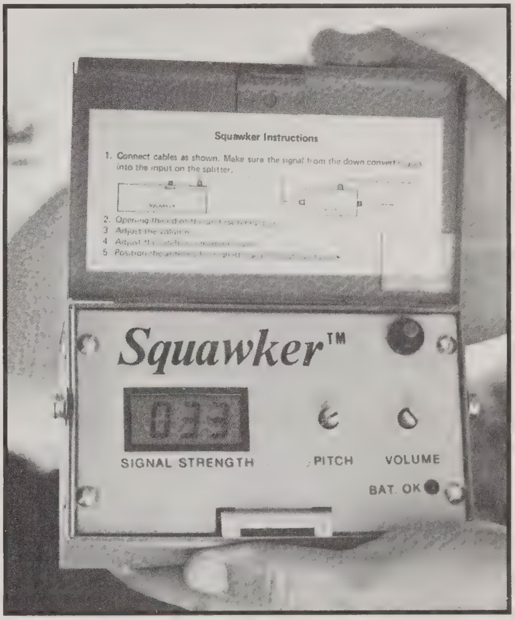


Figure 4-95. The Squawker. *This instrument has a battery powered digital signal strength meter as well as an audio tone which changes in frequency as power increases when peaking the antenna. (Courtesy of Focii Antenna Systems).*

Figure 4-96. The Tweaker. *This test instrument is battery powered and has a sensitive analog dial to indicate signal power. (Courtesy of Northwest Satlabs, Inc.).*

If the feedhorn is improperly aligned, as much as 2 decibels of signal can be lost. This is equivalent to reducing the performance of a 10 foot dish to that of an 8-footer. Remember that in addition to centering the feedhorn and correctly setting the focal length, the body of the feed should not be twisted relative to the face of the dish. If it is, more gain can be lost from shadowing and misalignment.

Note that many manufacturers set the focal length so that no adjustment can be made. This simplifies and speeds installation but loses some "tweaking" power.

I. FINE TUNING THE ELECTRONIC SYSTEM

Now move the equipment to its final installation location, if this is not already done. Check that all satellites are properly tracked. Usually, the IF gain should be adjusted to get the best picture. And, when optional, the skew adjustment knob should be set near the center of its range of movement by adjusting the appropriate potentiometer or programmed setting. Make sure that the polarity probe is not sitting at the end of its range of movement by going outdoors and observing its position or by feeling the motor for vibration when the skew knob is set at its end positions. Note that Houston Tracker actuators have a timer which shuts the motor off in 5 seconds so this check will need to be made with two people, one at the receiver and one at the dish. Both the IF gain and skew fine adjustments are usually accomplished by rear or bottom panel adjustments. Be sure that the polarity probe is not sitting at the end of its range of movement.

Read the manufacturer's instructions carefully to make sure that all that can be done has been done. These instructions are invaluable during the next step, programming the receiver and actuator.

If pictures are not as perfect as they should be in-doors, check that all connections to the receiver are secure. Another source of difficulty could be a customer's television which will occasionally require fine tuning to the channel modulated by satellite receiver. This channel may never have been used before in watching off-air programming but could already have been adjusted if the customer had been a cable TV subscriber or had used a VCR. To guarantee that the customer's TV set is capable of producing good pictures a VCR or a portable signal simulator which generates test patterns on channel 3 or 4 is an effective tool.

J. PROGRAMMING THE RECEIVER AND ACTUATOR

Each brand of programmable receiver and actuator is different. Follow the manufacturers instructions carefully in programming. Some systems such as the Houston Tracker IV and V require special interfacing wires between the receiver and actuator. These should have been completed the night before the installation. Programming is always much easier the second time around. Keep this reassuring fact in mind in times of trouble.

Remember that some remote controls require that batteries be added by the installer. Always have a supply on hand.

K. WATERPROOFING

Water in the form of rain, ice or snow is the chief enemy of a satellite TV system. It can corrode connectors, accumulate in feedhorns or weigh down antennas. Once the system has been tested and is working perfectly, the waterproofing team gets on the job. This task should be saved until the end when the system is working. So if a component must be replaced, water seals do not have to be broken and then redone.

All connectors and junctions where water could enter should be sealed. Some caulks are made with ammonia or lactic acid which can corrode metals; others harden, become brittle and crack. A sealant which stays soft like Coax-Seal® (Universal Electronics, Inc.), a hand-moldable, non-corrosive rubbery material, is recommended.

The equipment at the dish focus should be put under a protective cover, an LNA cover. This small expense is excellent insurance. If the downconverter is mounted below the dish, it should be placed in a waterproof box which is either opened or has drain holes on the bottom. Make room for the entry and exit of coax; remember that these should not be overly bent. Use drip loops.

In climates having snowy winters, the dish should be located so that it will not be pushing snow as it tracks the arc. If at all possible, leave adequate space under the bottom rim so a lawnmover will not run into and damage the dish. Clear away extra space if necessary.

Be sure that water cannot accumulate anywhere on the mechanical system. There have been cases where water has collected at the bottom of mounts which were opened at the top but closed at the bottom. The water froze, split the tubing and weakened the mount.

After waterproofing the cable, the trench can be covered up and the sod replaced. At this point, the installation is judged to be properly functioning.

L. CONNECTING STEREO PROCESSORS AND OTHER ACCESSORIES

Every installation will have a slightly different requirements for in-house equipment. Extra TVs, stereo processors, modulators and even large screen TVs may be needed. But remember that installing peripheral equipment is usually an easy task if the design is clearly laid out and planned.

Extra TVs

One satellite receiver can power two or three TVs without amplification or any number of televisions with the necessary line amplifiers. All that is needed are splitters. These divide the video signal into 2, 3, 4 or even more equal signals. The placement and type of splitters used depends upon the location of all the TVs. For example, assume that there is one set adjacent to the video receiver and three at the far end of the house. A 2-way splitter would be used at the receiver output to drive the nearby television and a trunk line having a 10 to 20 dB line amplifier would be connected to a location near the other sets. There a 3-way splitter would divide the signal. This is certainly a much better strategy than using a 4-way splitter at the receiver and running three long cables.

The type of cable used depends upon the distance travelled and number of televisions connected. For short distances, RG-59 is adequate. Up to 200 or 300 feet RG-6 can be installed. RG-11 can be used for longer trunk lines. However, for example, if 30 televisions all in close proximity to the receiver were driven by this reciever, it would still be necessary to use lower loss RG-6 or RG-11 since the original signal would be split or tapped so many times. The rule is common sense and minimizing cable runs.

Line amplifiers which are easily inserted via F-connectors into a trunk line system may be required for extensive distribution systems.

If a multiple receiver system is being installed, splitters rated at higher frequencies are required. For example, if three block downconversion receivers are being used to drive three different TVs, the IF line in from the dish would be divided before entering the first receiver. This could be accomplished by either two 2-way splitters or one 3-way splitter depending upon which resulted in shorter cable lines. These three outputs would be used as IF inputs for each receiver. Sometimes it is difficult to find a 3-way splitter rated for these higher frequencies. Then a 4-way splitter would be used and one port would be terminated or capped (see Chapter V for more details on these configurations).

Stereo Processors

Many satellite receivers have built-in stereo processors. All that is necessary to hook them into a home stereo system are two leads connected by RCA jacks, one for the left and one for the right sound channel.

Stand-alone stereo processors are driven by the baseband output from a satellite receiver. This output is most often via a RCA jack. The receiver instruction manual should clearly specify which output is dedicated to a stereo processor.

Modulators

Occasionally it will be necessary to modulate the receiver composite audio and video signal onto channels other than the standard channels

3 or 4. For example, three block downconversion receivers may be used to send three different channels along one trunk line to many televisions. In order not to interfere with off-air channels, it may be necessary to modulate onto UHF channels 20, 22 and 24 or onto VHF channels 5, 11 and 13 (see Chapter V for more details). In general, it is best to modulate onto VHF channels since cabling losses are much higher in the UHF frequency range.

Modulators ranging in quality from those built into satellite receivers to commercial brands providing 30 to 60 decibels of amplification or more and excellent channel isolation are available. They generally require both an audio and video input and have one RF output. They usually have both audio and video level adjustments which can be adjusted to fine tune a well- designed distribution system (see Chapter V for more details).

M. TOOLS REQUIRED

The old boy scout adage "be prepared" applies to a satellite TV installer. Having to make an extra round trip of 40 miles for a N-connector coupling or a 75 to 300 ohm transformer is certainly a waste of valuable time and money.

Tools of the trade can be carried in a small pickup or a thoroughly equipped van. The equipment needed depends upon what types of antennas are being installed, the climate and how a dealer wants to organize his installations. For example, separate crews can be used to plant the pole, assemble the dish and run the cable and then to do all the electrical and tweaking work. Or one crew can complete the job in one visit.

Heavy Machinery

Heavy machinery includes vehicles needed to transport poles and dishes and all the equipment required for excavation and concrete work. Although some 10-foot mesh dishes are packaged to fit into a small car, spun or stamped antennas come in one piece and require a larger vehicle for transportation. At very least, a small pickup truck or a single or tandem axle trailer which can be pulled behind a car should be owned by any serious dealer.

Excavating tools include a wheelbarrow or a portable cement mixer, a pick ax, breaker bar, hoe, rake, hole digger and shovel. Others may be required in different situations.

Major Tools

This category includes all those tools required for every installation. This includes an inclinometer and compass, extension cord, wire strippers and carpenter's level among others.

Often-Needed Tools

Tools on this list are needed occasionally in special situations. For example, if no power is available at the site a portable generator may be required. Or for long pole supports, an extension ladder may be needed.

Connectors, Cables and Other Accessories

This category includes all those small items that are most often and sometimes always required on an installation. These should always be on hand for both installing and troubleshooting. The lack of such a small but essential item could be a source of great frustration.

The installer's equipment checklist below is provided for convenience. Another in a different form listing somewhat different equipment can be prepared to suit a dealer's tastes. However, using a checklist before leaving the shop to travel to either install or troubleshoot a system is a highly recommended practice.

N. COLD WEATHER INSTALLATIONS

Doing an installation in very cold weather can be uncomfortable. However, there are many factors to consider other than discomfort. Things that are taken for granted do not necessarily happen as expected. For example, electrical tape which normally sticks perfectly well becomes brittle and useless. It is necessary to buy a good brand and keep it in a warm place or a pocket until it is needed. Or low power solder guns cannot produce enough heat to melt solder. A very large gun is needed at 25° F below zero. In these cases, crimp on connectors, not solder, may be chosen.

When it is sub-zero, fiberglass becomes brittle and can shatter. Many fiberglass dishes have been damaged in these conditions by overtightening the bolts that hold the dish to the mount. The answer to this problem is either to be very careful or assemble dishes in-doors in cold weather, if possible. If this is not possible, let the unassembled pieces sit in the warm sun under a plastic covering.

Concrete will not set properly in very cold weather unless the right precautions are taken. Two percent calcium chloride must be added to prevent freezing; and the surface must be covered with a blanket, straw or another insulating material until it cures. Other binding materials like Dish Set® set more slowly when cold. A simple practice to aid the hardening of either this material or a fast setting cement is to place the pole in-doors or under the exhaust of a running vehicle to warm it up just prior to its being planted.

Some brands of silicone sealants will not harden. Make sure that a silicone designed specifically for cold weather is used. Other products behave in surprising ways when cold. For example, one of the authors purchased 2,000-12 inch wire ties one summer expecting that these would have a long service life. When winter came this brand of ties were so brittle that they would snap. When warmed up they were fine, but at below freezing temperatures there were useless. Another brand manufactured specifically for cold weather had to be ordered. Similarly, most non-colored nylon wire ties will fail after only one year's exposure to sunlight. Black, blue, brown or specially UV-stablized brands will, however, last many years.

Tools can become very brittle in the cold, especially at temperatures below -10 °F. For example, ends of screwdrivers snap off and crescent wrenches break. A solution is to use oversized wrenches which have greater lever-

TABLE 4-11. INSTALLER'S EQUIPMENT CHECKLIST

Heavy Machinery

_____ Pickup Truck or Trailer
_____ Wheel Barrow or Cement Mixer
_____ Post Hole Digger or Power Auger
_____ Shovel
_____ Pick Ax
_____ Rake and Hoe
_____ Bucket and Hose
_____ Breaker Bar
_____ Trencher

Major Tools

_____ Inclinometer
_____ Compass
_____ Signal Strength Meter
_____ 100 Foot Extension Cord with 3 or 4-Way Adapter
_____ Extra TV or Monitor
_____ Multimeter (volts, ohms, etc.)
_____ Hex Crimp Tool for RG-6 and RG-59 Connectors
_____ Wire Strippers/Exacto Knife
_____ Tape Measure (at least 100 feet)
_____ Soldering Gun (20 and 40 watt) and Solder
_____ Carpenter's Level
_____ Flashlight and/or Florescent Light
_____ 1/2 Inch Heavy Duty Drill, Switchable to Hammer Operation, and Bits
_____ 3/8 Inch Variable Speed Drill and Bits
_____ 16-Ounce Hammer
_____ Hack Saw and Blades
_____ Large Diagonal Pliers
_____ Large Long Nose Pliers
_____ Small Long Nose Pliers
_____ Vise-Grips
_____ Assorted Screwdrivers
_____ 3/8 to 1-1/8 Set of Opened Ended Wrenches
_____ Set of Socket Wrenches
_____ Small Set of Metric Sockets
_____ Large and Small Crescent Wrenches (12 to 15 Inches)
_____ Awl or Center Punch (for Aligning Holes in Dish Petals)
_____ Set of Allen Wrenches
_____ A Short Ladder
_____ String and Tape
_____ 1-1/2 to 2 Inch Electrical Conduit, Solvent and Sweeps
_____ Metal File and Assorted Sandpaper
_____ 5/8 by 18 Inch Wood Drill Bit
_____ 5/8 by 12 to 18 Inch Masonry Bit

Often-Needed Tools

_____ Extension Ladder
_____ Generator
_____ Fish Tape (for Feeding Cable Down Walls)

Connectors, Cables and Other Accessories

_____ F-Connectors
_____ F-to-F Bullets (F-81 Barrels)
_____ N-Connectors (UG-57 and UG-29)
_____ Right Angle and Straight F- and N-Adaptors
_____ RCA Jacks, Molex Plugs, Lugs, Scotch Locks and Assorted Adaptors
_____ Rolls of Direct Burial, RG-6 and RG-59 Cable
_____ RG-213 or 214 Pigtails
_____ 75 to 300 Ohm Transformers
_____ A/B Switches
_____ 2-, 3-, and 4-Way Splitters
_____ 75 Ohm Terminators
_____ Spare Fuses and Voltage Regulators
_____ Electrical Tape
_____ Box of Assorted Wire Nuts
_____ Box of Romex Staples
_____ Can of Touch Up Spray Paint
_____ Coaxial Sealant
_____ Non-Conducting and Non-Corrosive Sealant
_____ A Spare Polarotor Servo Motor
_____ Surge Protector with Multiple Outlets
_____ 10 and 20 Decibel Amplifiers
_____ Ground Rods and Heavy Gauge Grounding Wire
_____ T-25 Arrow Roundtop Staple Gun
_____ Box of Assorted Wires Nuts

age and need less torque, such as 20 inch instead of 12 inch crescents. Plastic containers easily break. Knobs also snap off receivers and TVs. Some brands of receivers do not work properly below a certain temperature. A recommended method is to keep the receiver and television in a warm car or truck during testing by running an extra long pigtail from the LNA. Many types of cable will not unbend when cold and should be kept warm until needed. Some cables are made especially for such use. Center conductors of some coaxial cables will snap in two when cold. Therefore, care should be taken when uncoiling coax in cold weather.

Cold metal can be dangerous. For example, one dealer was working on a system when the chill index was -65°F. He went inside to check a picture and ran back to raise the elevation adjustment without his gloves. A crescent wrench which had been sitting outside instantly froze to his hand and could only be removed by running water over it. It is just as easy to pull skin off a hand by tightly grasping a very cold mount. Always wear a good pair of gloves.

Many problems can be traced to freezing of water which enters components either by condensation or leakage. Water left inside a waveguide can easily freeze and crack the housing. Even small amounts of condensation can cause problems for polarity selection motors in extremely cold climates. Ferrite devices having no moving parts are recommended in such situations instead of mechanically rotated probes. There have been cases of water collecting in mounts or actuator motors and cracking the surrounding metal. The use of drain holes, effective sealants, LNA/feedhorn covers and other protective measures are expecially recommended in such climates.

A properly equipped dealer should be able to install in any weather - be it rain, snow or blizzard. For example, in very cold weather prefab concrete bases poured in a shop can be trucked to an installation site. But there are times when it is just to cold or wet or snowy to warrant the effort. Use this time to build dishes and mounts in the shop or to pour slabs for future use. Or take a vacation and relax - maybe watch satellite TV.

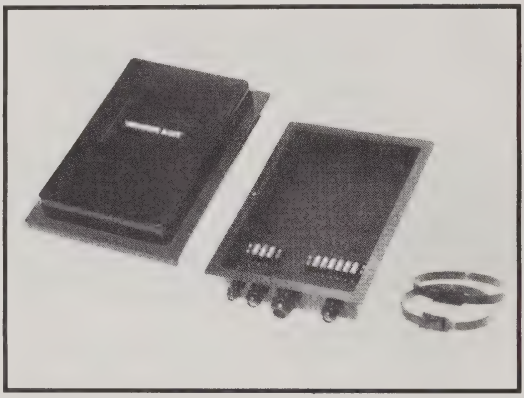


Figure 4-97. Downconverter Box. *This weatherproof downconveter box is tied to a mount or supporting pole by two clamps. (Courtesy of M.B. Sales).*

O. CUSTOMER RELATIONS

Customer relations are common sense behavior, most of the time. However, sometimes common sense must be learned, often at a high cost. The most important piece of common sense information is be punctual.

Do-It-Yourselfers and Do-Unto-Others

Some customers have an amazing amount of technical know-how and can teach most any dealer some interesting tricks and methods. Often a dealer who knows how to spot such people will make a sale where others have failed. Popular Science and similar magazines do not sell to millions of readers for no reason.

Some customers may want to participate in an installation by doing something as simple as helping to assemble the dish, plant the pole or run cable lines to actually completing the whole job except for the final wiring and tweaking. Ninety percent of the time they can do an excellent job with the proper guidance and become a source of many referrals. Other customers are pleased to do the entire installation knowing that a competent dealer is ready waiting in the wings when needed with advice. Such installations are often an example of fine workmanship.

Whether or not a customer wants to participate, every installation should be treated as if it were the dealer's own home. It should be a source of pride and referrals and should last for years. Before leaving a site, a professional will take one last look around the premises in an attempt to see if anything else could be done more perfectly.

Contracts and Warrantees

Never make a sale or do an installation without a signed contract. Customers should be informed of all warrantees and special conditions of this legal document. Each section of the contract should be explained so that there are no hidden expectations or unwanted surprises. Contracts protect both the dealer and the customer. Whenever a situation deteriorates to the point that a lawyer must be called in, both parties usually have already lost.

P. DOCUMENTATION

It is important that records be kept of each installation in case any problems arise in the future. This documentation for both the customers's and installer's records should include the following:

INSTALLATION DOCUMENTATION

Date:
Location:
Date of Installation:
Original Site Map:
Dish Type:
Mount Type:
Pad or Pole Support:
Low Noise Amplifier Temperature and Type:
Receiver Make:
Actuator Make:
Type and Length of Cable:
Number of TV Sets:
Any Special Installation Details:

During the installation a table outlining the measurements taken during tweaking should be created. This will prove very useful when performance comparisons might be required at a later time. Remember, however, that as satellites age their transponder power will decrease and these numbers will slowly fall.

SIGNAL STRENGTH COMPARISON TABLE

Date: March 10, 1986
Location: R.F. Jones, St. Laurent, Quebec.

Satellite	Transponder Number	Signal Strength
Satcom I	20	5.0
Satcom III	20	5.5
Westar IV	20	4.7
Telstar 302	20	6.4
Satcom IV	20	5.7
Satcom II	20	6.2

SITE SURVEY WORKSHEET

No.: ____________________
Date: ____________________

Customer Name: ____________________
Address: ____________________
City ____________________ State ________ Zip ________
Phone: (Home) ____________________ (Work) ____________________
Lead From: ____________________ Salesman: ____________________
Map

1) Size and make of dish and mount: ____________________
2) LNA noise temperature: ____________________
3) Type and style of feed: ____________________
4) Receiver Type: ____________________
5) Stereo Type: ____________________

6) Feet of cable? ______
Note: (If over 300′, contact office)
7) Feet of conduit? ______
8) Number of wall plates? ______
9) Make and model of actuator? ______
10) Number of extra TV's to be hooked up? ______
If so, will there be problems running cable (i.e. finished basements, second stores, etc.?) ______
______
11) V.C.R. or stereo hook up? ______
12) Anything in the yard or walls that could be in the way to run cable (i.e., sidewalks, yard sprinklers, alarm systems, etc.?) ______
______
13) A slab installation or pole mount? ______
14) City ordinances are in effect? ______
If permit is necessary, be sure one is obtained **before** work can start.
15) Does customer want a five year extended warranty? ______
If so, from what company? ______
16) Does the customer have cable TV? ______
To be disconnected by whom? ______
17) Does customer want a program guide? ______
Which type? ______
18) Kind of outside (local) antenna in place? ______
19) Type of waterproof box for electronics? ______
20) Number of A/B switches on combiners? ______
21) Date of installation requested: ______
22) Comments:

PRE-INSTALLATION WORKSHEET (Part 1)
(Courtesy of Mark Widner)

Customer No.: ____________
Date: ____________

Customer Name: ____

Equipment:

Amount	Item	Make	Model	Serial Number
	Dish			
	Mount			
	Feed			
	LNA/Feed Cover			
	LNA			
	RG-214			
	Receiver			
	Downconverter			
	Actuator			
	60/80 MHz Filter			
	Waterproof Box			
	Combiner			
	A/B Switches			
	Line Amplifiers			
	Splitters			
	Wall Plates			

	Initials
1) All electronics checked before leaving office:	______
2) Have back-up electronics on hand	______
3) Enough wire for installation of primary TV as well as second TV?	______
4) Proper tools in installation vehicle:	______
5) Customer contacted before leaving:	______
6) All lights and signals on vehicle and trailer checked	______
7) Invoice for proper amount to collect from customer: checked	______
8) Pole mount, set-up: checked	______
9) Connector kit: checked	______
Time left office:	______

POST-INSTALLATION WORKSHEET
(Courtesy of Mark Widner)

Customer No.: ________
Date: ________

Customer Name: ________

		Initials
1)	How many feet of wire needed?	______
2)	All wires buried and area around mount cleaned up?	______
3)	All wires waterproofed and all holes in house sealed?	______
4)	Any back-up equipment used? If so, what serial numbers and equipment was changed?	______
5)	All TVs, stereos, VCRs hooked up?	______
6)	Customer signed all paper work and all monies collected in full?	______
7)	Were any in-line splices needed? If so, give location and reason:	______
8)	Sign of terrestrial interferences, or blockage by trees, buildings degrading picture to any noticeable extent?	______
9)	If slab used, is the ground prone to settling or high moisture?	______
10a)	If conduit used, were weatherheads installed?	______
10b)	If no conduit used, was wire protected at ground entry near both the dish and house?	______
11)	All wires inside house tacked up neatly and not near any furnace or water heater exhaust stacks?	______
12)	On a scale of 0 to 10, rate the picture. (10 is studio quality):	______
13)	Both protective caps placed on the polorator?	______
14)	On the site survey worksheet, draw on the map of the customer's property how the wires were run:	______
15)	If wall plates needed, were they all installed?	______
16)	**Comments:**	

Time in: ______

Returned all back-up equipment ____________ (initial of inventory manager)

V. MULTIPLE RECEIVER SATELLITE TV AND DISTRIBUTION SYSTEMS

Satellite TV signals can be relayed in combination with off-air broadcasts, VCRs, video games or even closed circuit television messages to any number of television sets. There is really no limit to the design possibilites once a sufficiently powerful satellite signal has been captured and processed.

The first step is to understand the different configurations possible with a conventional or block downconversion satellite TV setup. This ranges from a simple one receiver/24 channel system to a more complex multiple receiver/dual feedhorn/24 channel design. Next, distribution systems are examined in more detail. It will be clear that a wide range of designs are possible. But all are really quite simple to understand if the different pieces of this jigsaw puzzle are independently studied.

A. THE BASIC COMPONENTS

The most complex configurations of satellite reception equipment are pieced together from basic components including a dish, feedhorn, LNA, downconverter, cable, receivers and televisions. These are then combined with splitters, line amplifiers, attenuation pads, terminators, DC power blocks, A/B switches, combiners and coaxial relays to create any combination desired.

Televisions

Televisions function best when their input signal level is between 0 and 3 dBm, although the optimal levels can vary between sets. Remember that 0 dBm equals one millivolt; so 3 dBm is double that or 2 millivolts. When signal levels are above approximately 3 dBm some brands of televisions can be overdriven, and pictures will be distorted. However, most TV sets have AGCs (automatic gain circuits) which compensate for overly strong signals, so powers in excess of 3 dBm can be managed, to a point. But the 0 to 3 dBm is a good target range which should be achieved for best results. Realize that if the ratio of signal to noise power has been allowed to drop too low or is "in the mud," no level of amplification will improve the situation because at this point as much noise will be amplified as signal. But if power levels exceed 3 dBm, attenuation pads can always be used. Therefore, too much power is never really too much but allowing signal strength to deteriorate can be a serious problem.

Note that many older televisions will often have a 300 ohm, two-screw VHF input where the familiar flat TV leads can be attached. Signals from satellite receiving equipment as well as from other devices are transmitted by 75 ohm coax and require F-connector inputs. So a 75 to 300 ohm matching transformer, known as a balun (derived from balanced-unbalanced), must often be used in the transistion from the coax to the television VHF terminals. The transformer matches the impedance between the coaxial cable and the television input to allow maximum signal power to be transferred.

Cable, Connectors and Splitters

Cable, connectors and splitters are the conduits for carrying signals between any number of locations. Each type has characteristic power losses which depend upon frequency. These must be accounted for when designing systems.

Attenuation or signal loss in standard 75 ohm cable such as RG-6, RG-11 and RG-59 have been detailed earlier in this manual. A good ballpark loss figure to use for RG-59 cable, the standard type used for distribing television signals in small systems, is 2 dB per 100 feet at 50 MHz and 4 dB per 100 feet at 200 MHz. Note that 50 MHz is right at channel 2 and 200 MHz is just below channel 13 (see Tables 2-7 and 2-8 and the cable attenuation graph in Chapter 4.).

Coaxial cables can be purchased in any lengths usually up to a maximum of 1000 feet. And different colors such as black, beige or white are available and can be chosen to improve the look of any installation or to help conceal the cable.

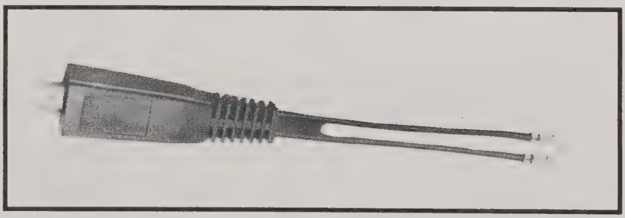


Figure 5-1. A Matching Transformer. *This device is used with television sets which requires 300 ohm twin-lead cable inputs. Today most sets are manufactured with 75 ohm F-connector VHF inputs. (Courtesy of MACOM Industries).*

Splitters do just what the name implies, divide the signal into two or more branches. They may also be used to combine signals in the correct situation. Splitters are designed to handle a specified frequency range. For example, when dividing a 950 to 1450 MHz block downconversion satellite signal, a splitter rated up to 1450 MHz must be used or losses will be too high. Some brands of splitters also have built-in bandpass filters so that frequencies below and sometimes above the designed range are attenuated. Limiting the bandwidth can protect cables from ingress interference. Typical insertion losses for two-, three-, four-, eight-, and sixteen-way splitters are listed below in Table 6-1:

TABLE 6-1 SPLITTER LOSSES IN EACH LEG

Type of Splitter	Loss in Decibels
2-way	3.5
3-way	3.5 and 7
4-way	7
8-way	10.5
16-way	14

A 2-way splitter cuts the signal a little more than in half (since a 3 dB reduction is a halving of power). A 3-way splitter has one -3.5 dB and two -7 dB legs. For example, if a signal of 3 dB is divided in a 4-way splitter each output leg would have 3 dB less 7 dB or -4 dB of signal output, which is not really enough to produce a studio quality television picture. If this signal was then relayed down 100 feet of RG-59 cable, additional losses of 4 dB at 200 MHz would result in a final signal of -8 dB at the television input. Therefore, amplification would be needed before the 0 dBm level was reached. Remember that line amplifiers should be used before cable losses cause a situation where noise power becomes too large compared to signal power.

Line Amplifiers and Tilt

Line amplifiers which are inserted via F-connectors directly into a coax line are available for boosting signals from either a a single channel or a whole range of channels. Most of the simpler units are powered from the DC voltage relayed down the coax. More costly commercial amplifiers draw current from a regular wall outlet and convert it to DC power. This is similar to the way preamps designed for distributing off-air broadcasts operate.

Amplifiers can have either fixed or adjustable gain. Some amplifiers designed for longer runs have gains which increase with frequency to compensate for the increased attenation of signal at these higher frequencies. This is called tilt. For example, if RG-59 is used for especially long runs, a tilt of about 2 dB per hundred feet between 50 and 200 MHz (channels 2 and 13) should be used. This is based on the difference between the 4 dB and 2 dB loss per hundred feet that this coax has at these two frequencies. For example, if a cable run of 300 feet were used, a line amplifier delivering 26 dB at 200 MHz and 20 dB at 50 Mhz would properly compensate for the 6 dB difference cable losses between these frequencies. Then the output after 300 feet of cable would be flat across all frequencies.

Attenuation Pads

An attenuation pad, or more simply a pad, is used to reduce the strength of an overly powerful signal. Pads are small, inexpensive devices which insert directly into a coax line with F-connector fittings. They are available with either fixed or variable attenuations and occasionally with built-in tilt compensation. Most pads are not designed to pass DC power so they cannot be used in the line between receivers and downconverters.

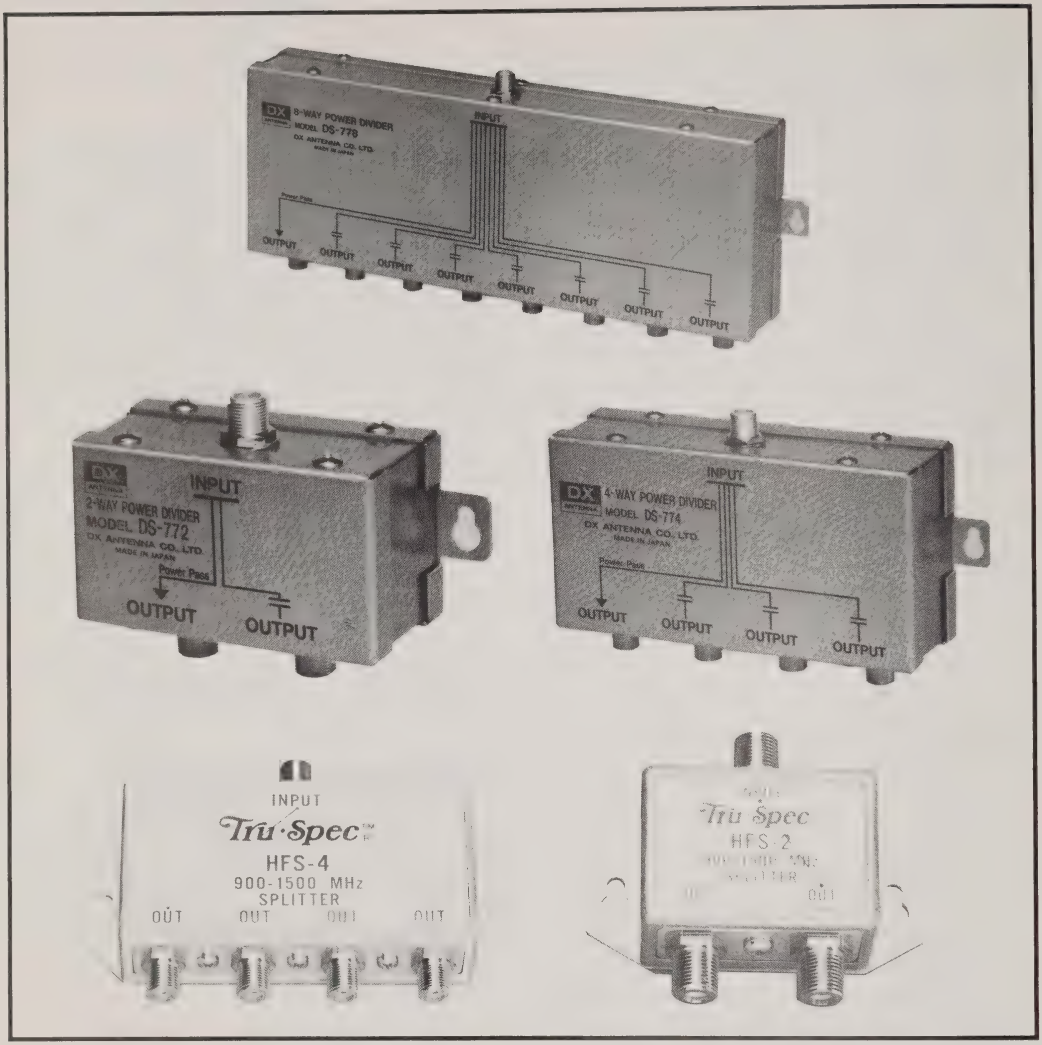


Figure 5-2. Splitters. *These 2-, 4-, and 8-way splitters each pass DC power through only one port and block DC power through all others. The Tru-Spec splitters are rated for 900 to 1500 MHz (Courtesy of DX Communications and MACOM Industries).*

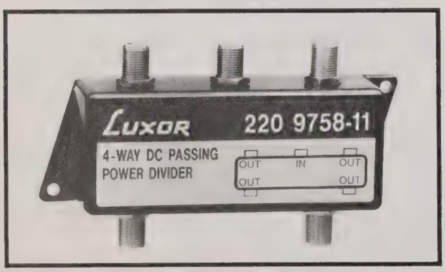


Figure 5-3. Power Passing Splitter. *This splitter passes DC power through all of its ports. (Courtesy of Luxor North America Corporation).*

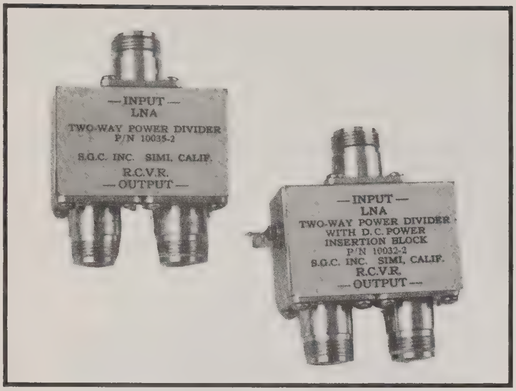


Figure 5-4. Power Blocking Splitter. *These 2-way power dividers are identical except that one has an internal DC power block. Both have insertion losses of just over 3.2 dB. (Courtesy of Satellite Ground Components, Inc.).*

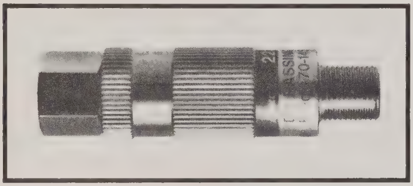


Figure 5-6. Attenuation Pads. *This pad has one male and one female port and can easily be inserted into a F-connector line. It provides 10 dB of signal attenuation and passes DC power. (Courtesy of Luxor North America Corporation).*

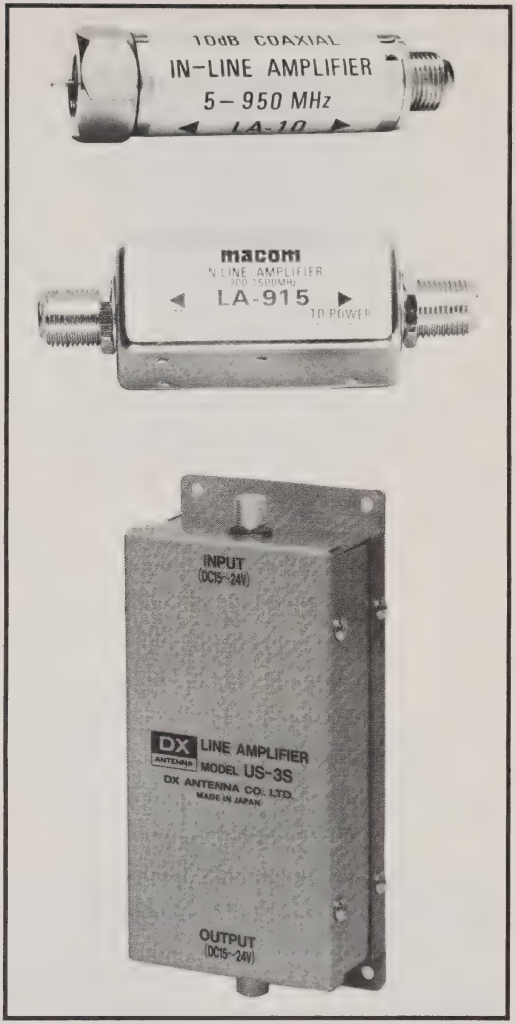


Figure 5-5. Line Amplifiers. *The LA-10 line amplifier, called an LA-10 bullet, is rated for 5 to 950 MHz and cannot be used for some brands of block receivers operating at higher frequencies. Both the DX US-3S and the MACOM LA-915 amplifiers are rated for use from 900 to 1450 MHJz. These line amplifiers draw their operational power from receiver IF DC voltages. (Courtesy of DX Communications and MACOM Industries).*

Terminators

Any output port on a television distribution system must end in an appropriate device such as a television set, a satellite receiver or a terminator. If not, the opened port could pick up interference or cause signals to be reflected back into the system as "ghosts." A terminator for 75 ohm coax which simply screws onto a F-connector has a matching 75 ohm impedance and is nothing more than a resistor. It fools the cable into not being able to see an opened end or discontinuity at the unused port.

Figure 5-7. Signal Terminator. *This terminator is installed on unused N-connector ports on splitters rated for C-band frequencies. (Courtesy of Satellite Ground Components, Inc.).*

DC Power Blocks

A DC power block is a simple device which allows higher frequency television signals to pass unattenuated but which blocks the passage of any direct current. Therefore, DC blocks are used to isolate various components in a satellite system from DC voltages. This is accomplished by a circuit element called a capacitor which passes higher frequency signals but which blocks direct current.

Figure 5-8. Ferrite Isolator. *These components have a 60 dB isolation between input and output ports. (Courtesy of Satellite Ground Components).*

Figure 5-9. DC Power Block. *This power block which contains a capacitor, has an insertion loss of about 0.3 dB and is rated for 3.7 to 4.2 GHz. (Courtesy of Satellite Ground Components, Inc.).*

A/B Switches and Combiners

An A/B switch is used to select between either one of two input signals. High quality A/B switches have at least 40 or 50 dB isolation between its ports. This means that if a 10 dBm signal is present on the non-selected port, the output would see this signal reduced to -30 to -40 dBm (10 dBm minus 40 or 50 dBm which equals -30 or -40 dBm).

A signal combiner is used to combine and balance the powers of satellite and off-air signals. It can be used in place of an A/B switch. For example, a simple unit might take an input from the satellite receiver channel 3 modulator and another line from an off-air antenna.

Note that if two adjacent channels are being combined there is always the possibility that they will interfere with each other when a lower quality signal combiner is used. In any case, it is always important to balance the power levels of both the satellite and off-air signals before they enter the combiner. In order to eliminate interference between channels, it may be necessary to use a bandpass filter which cuts out the lower sideband and restricts the satellite TV input to a selected narrow range of frequencies. More about equalizing and separating adjacent channels is discussed below.

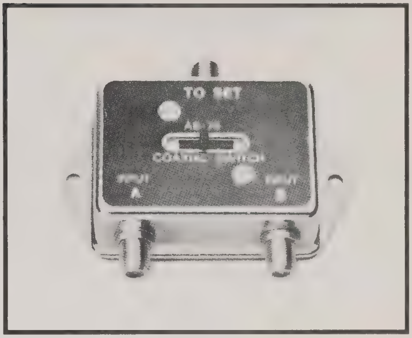


Figure 5-11. A/B Switch. *The A/B toggle switch chooses between one or the other of signals connected to the two input ports. (Courtesy of MACOM Industries).*

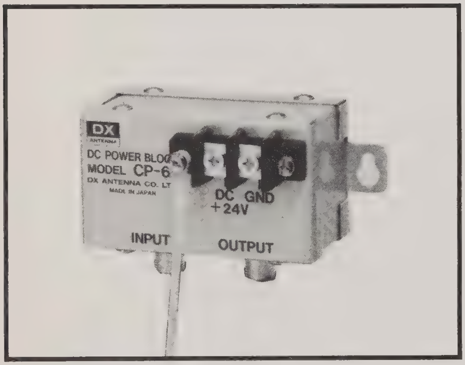


Figure 5-10. DX Power Block. *The CP-6, a DC power block, is inserted between a coaxial relay and downconverter. The input is connected to the downconverter and carries DC power which has been inserted by a two-conductor line coming from the receiver or power supply. The output which is connected to the coaxial relay has no DC power to interfere with the plus or minus 12 volt DC switching voltage used by the relay. (Courtesy of DX Communications).*

Figure 5-12. Channel Combiner. *This combiner accepts two inputs, an off-air line from a standard TV antenna and either channel 3 or 4 modulated satellite signal. The output is a combined signal. (Courtesy of MACOM Industries).*

Coaxial Relays

A coaxial relay is a switch which passes signal is only one direction at a time. Typically, 12 volts DC from the rear of a receiver or power supply is used to open or close the relay. Coaxial relays do not pass DC power and must be protected from excessive currents. A coaxial relay is nothing more than an electrically operated A/B switch.

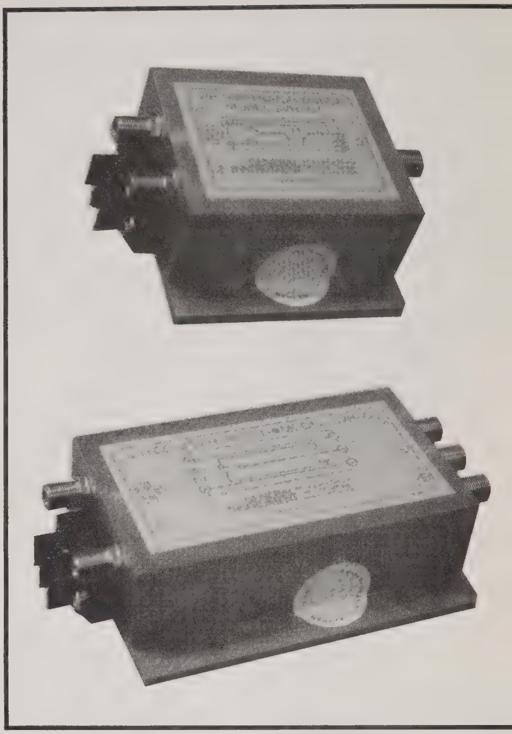


Figure 5-13. Coaxial Relays. *These two V/H couple switches are electrically controlled A/B switches The smaller one, the General Instruments SVH-10T has input terminals for vertically and horizontall polarized signals and a single output port. The ter minal strip under the input ports accepts plus an minus 12 volts DC which switches the output be tween V and H. This relay has a built-in terminato for the unused V or H line which is terminated. Th larger switch, the SVH-10, taps a portion of the V/H signals and passes them onto another SVH-10 o SVH-10T. Again V or H signals are chosen by plu and minus 12 volts DC on the terminal strip. Th SVH-10, unlike the SVH- 10T, does not require ter minators because it is not the last switch in the line (Courtesy of General Instruments, Inc.).*

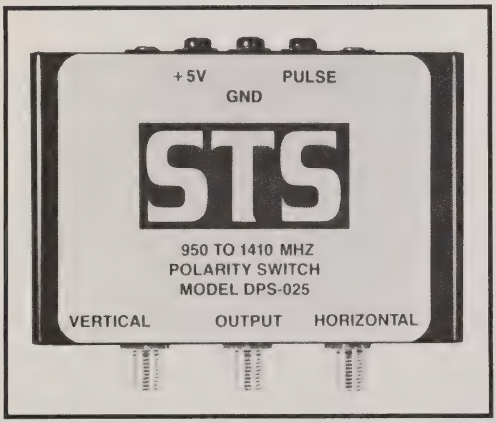


Figure 5-14. Polarity Switch. *This coaxial relay is controlled by the polarizer voltages coming from the rear of a satellite receiver. Remember that these connections are 5 volts, pulse and ground. (Courtesy of Satellite Technology Services, Inc.).*

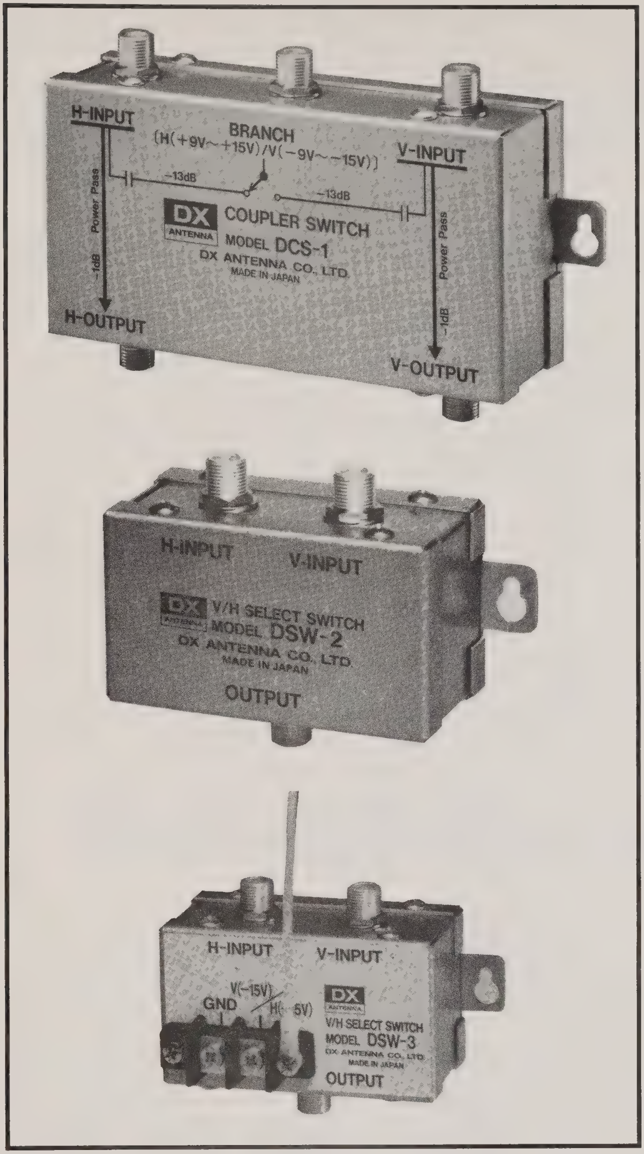


Figure 5-15. DX Relay Switches. *The DSW-2 V/H coaxial relay sends either vertically or horizontally polarized signals to the receiver depending upon the presence or absence of plus or minus 12 volts DC coming from the receiver. A strap on the rear panel of DX receivers changes their output voltages from one powering the downconverter to one sent up the cable to the coaxial relay. When using a DSW-2 an independent power supply and DC insertion blocks are needed for the downconverters. The DSW-3 is different from the DSW-2, because a separate two-conductor line is used to relay the switching voltages. The DCS-1 is identical to the General Instruments SVH-10. It taps either the H or V signal and sends the remainder to the next relay where it is again tapped to another 24- channel receiver. (Courtesy of DX Communications).*

TABLE 5-2. HORIZONTAL/VERTICAL SWITCHES TO RECEIVER INTERFACES

	Switch Types					
Receiver Type	STS DPS-025	CAL-AMP C515HV5D	DX DCS-1	DX DCS-2	DX DCS-3	MA/COM 4-WAY
S-SRb	Yes	Yes	No	No	No	No
STS-Block	Yes	Yes	No	No	No	No
Uniden 5000	Yes	Yes	No	No	No	Yes
Uniden 6000	Yes	Yes	No	No	No	Yes
Uniden 7000	Yes	Yes	No	No	No	Yes
M/A COM T1	Yes	Yes	No	No	Yes	Yes
M/A COM T2	Yes	Yes	No	No	Yes	Yes
M/A COM H1	Yes	Yes	No	No	Yes	Yes
Drake 424	Yes	Yes	No	No	Yes	Yes
Panasonic C-2000	Yes	Yes	No	No	Yes	No
DX-600	Yes	Yes	Yes	Yes	Yes	Yes
DX-700	Yes	Yes	Yes	Yes	Yes	Yes
Splitter Req'd?	MOD	No	No	DS-77	DS-77	No
DC Power Block?	No	No	Yes	Yes	Yes	No

B. SATELLITE TV CONFIGURATIONS

Each of the systems described below are diagrammed in the accompanying figures. These systems are taken as representative examples but are by no means the only possibilites. More complex or different systems can easily be designed by using the fundamentals learned in studying these examples.

The Basic System

The system most commonly encountered in the home satellite TV market consists of a single dish and video receiver combined with off-air broadcasts. Either an A/B switch or a 3/4 channel combiner is required to avoid interference between satellite and off-air signals. Note that an optional VCR can be used as an A/B switch. When its controls are set on "tuner" position the satellite signal is blocked. In the "camera" or "audio/video" position the direct video feeds into the VCR. Note that when the satellite audio/video signal feeds directly into the VCR and bypasses the receiver's modulator, recordings will be of higher quality than those from off-air signals.

Two lines of either RG-6 or RG-59 coax carry the downconverter power and RF signal from the dish. Channel selection voltages are also transmitted on the IF signal line. Many block downconversion systems now use a single coax, RG-6, to carry both downconverter power and RF signal.

A power supply for a VHF or UHF preamplifier is required in the regular off-air television antenna line if the signal is coming from a distant source or if there is a long cable run from the antenna. This will boost power levels to an acceptable 0 to 3 dBm level or more to the A/B switch or channel combiner input.

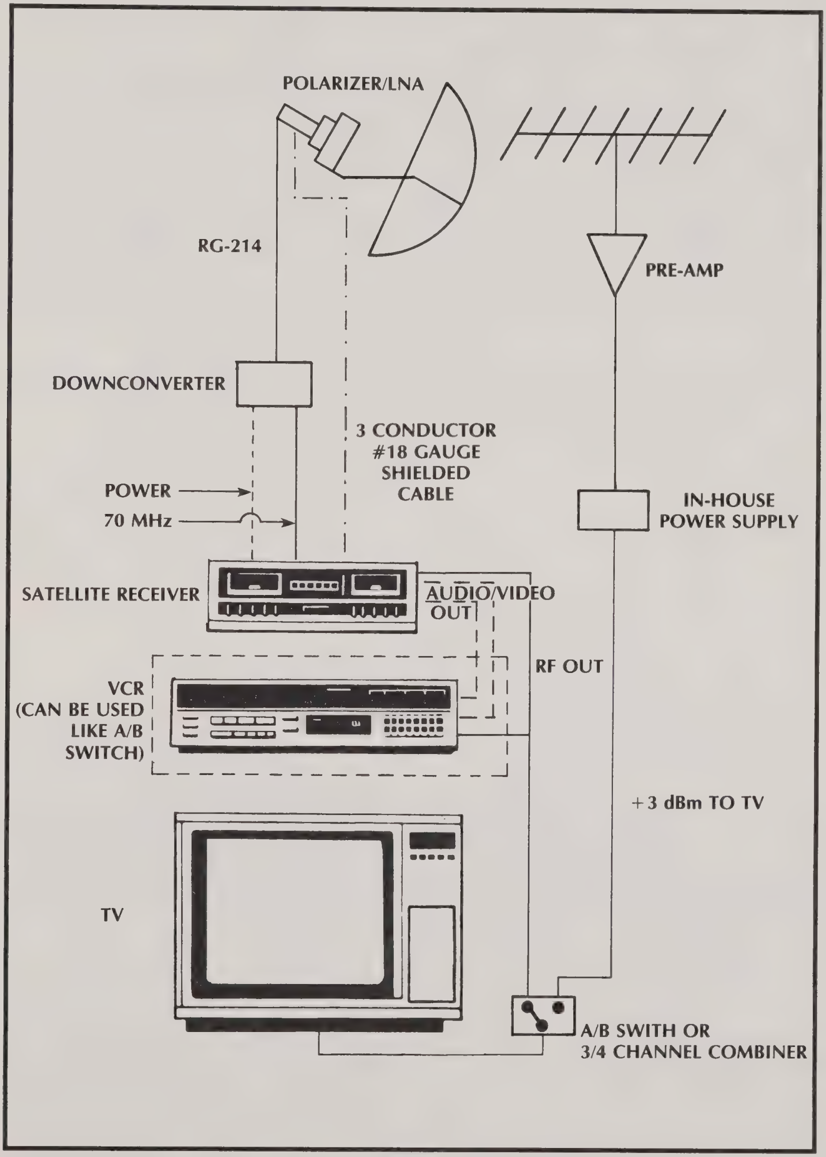


Figure 5-16. The Basic System.

Single Receiver, Two TVs and Extra Remote Control

This design is similar to the basic system except an extra TV has been added. The main television is located near the satellite receiver which is assumed to have an infrared, line-of-sight remote control. The satellite receiver can also be controlled from the second infrared transmitter, which is located in another room some distance away usually in the same house, by use of an extra remote control which communicates via the coax to the receiver. Use of such a "remote-remote" or an "extra link" can be very convenient for controlling the receiver from a bedroom or family room.

Note that the some brands of receivers and actuators such as the Houston Tracker IV Actuator and System V feature a radio relay, hand-held remote. The video receiver can then be controlled from any location within a radius of about 200 feet without the need for extra wires. Even though this remote operates on UHF frequencies close to the garage door opener range, it is rare that the two systems interfere with each other. Note that if extra range is needed on a UHF remote, additional antennas can be installed by running coax from the antenna output port to remote locations via standard coaxial cable and splitters.

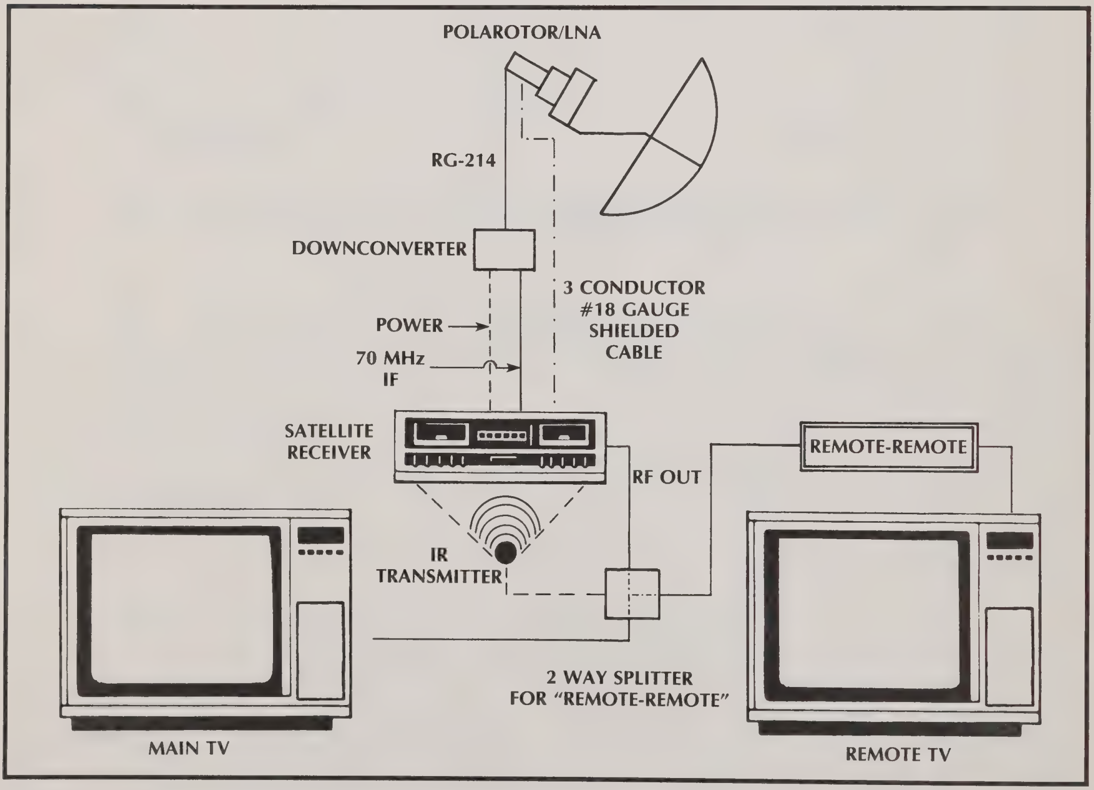


Figure 5-17. Single Receiver, Two TVs and Extra Remote Control.

Two Single Conversion Receivers/ 12 Channels

This system allows two separate single conversion receivers to have 12 channel independent control of channel selection. The master receiver is the only unit with control over polarity selection.

The key to designing a simple dual single conversion receiver system is a device called a 2-way power divider with ferrite isolation and DC power blocking between the output ports. This device is a relatively recent introduction and is manufactured by companies such as California Amplifier and Satellite Ground Components. It draws power through the downconverter from either receiver depending upon which has highest voltage at the time. So if either receiver were to be turned off, the LNA would still function. It has an internal amplifier

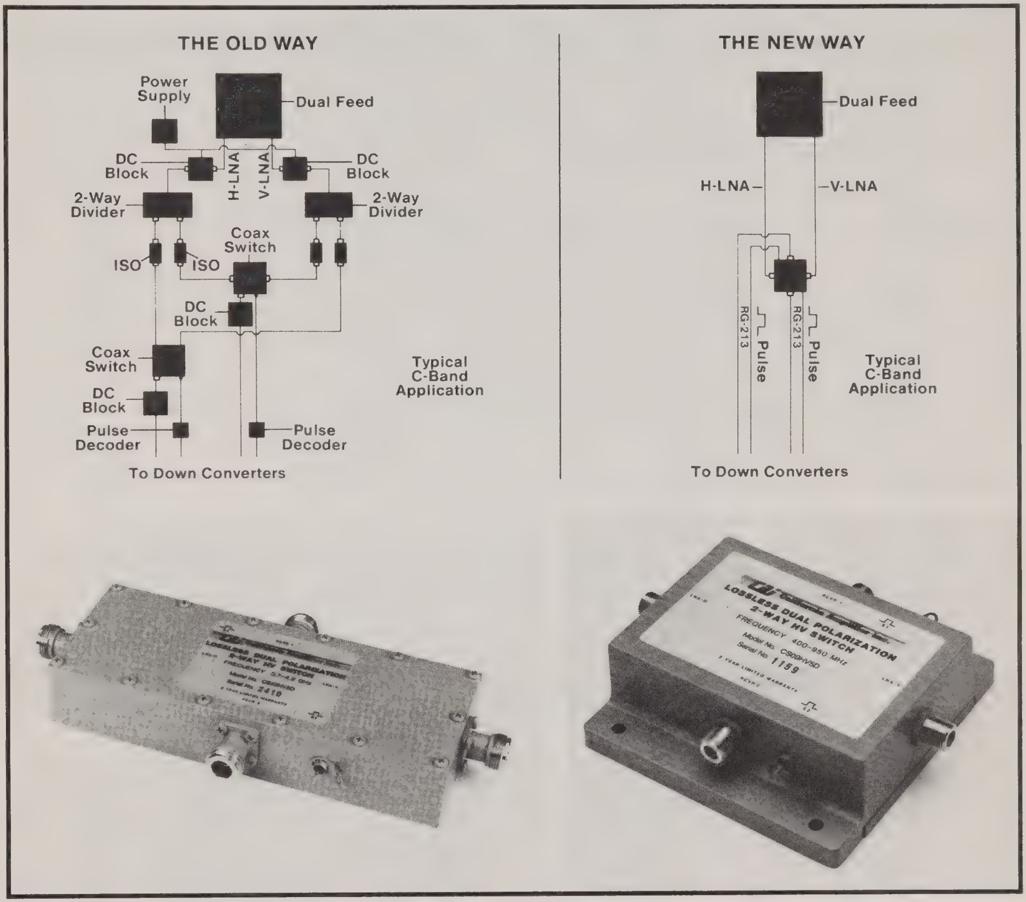


Figure 5-18. Dual Polarization H/V Switches. *These two California Amplifier lossless dual polarization 2- way H/V switches replace a host of plumbing components as shown in the "old way" diagram. The longer switch, model CS42HV5D, is rated for 3.7 to 4.2 GHz while the CS09HV5D is rated for 400 to 950 MHz. The former takes inputs directly from two LNAs while the latter is connected to two LNBs or block downconverters. Horizontal or vertical signal outputs are chosen internally by pulses from the satellite receivers. These switches have at least 55 dB isolation between receivers and 20 dB isolation between H/V ports. They pass power directly to the downconverter/LNAs and have built-in amplifiers to provide lossless operation. (Courtesy of California Amplifier, Inc.).*

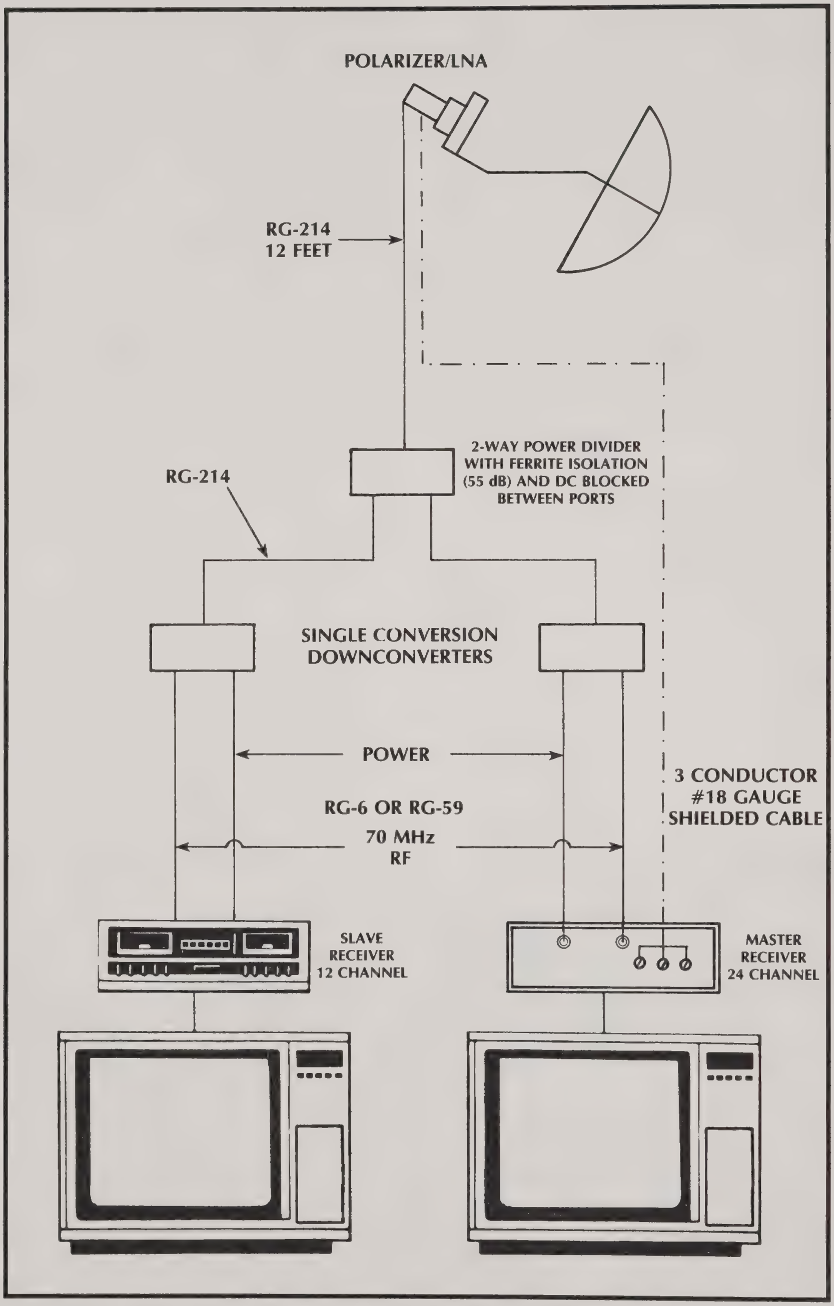


Figure 5-19. Two Single Conversion Receivers/12 Channels.

so that there is no insertion loss, in other words the signal is not weakened in passing through this device. It divides the microwave signal with 55 to 60 dB isolation between ports. Remember that at least this amount of isolation is required to eliminate cross-talk between single conversion receivers. As a result of this DC blocking and isolation, little or no DC power or signal leaks between the two separate lines.

Previously, a much more complicated plumbing job had to be done to realize the same objective. One DC power insertion block was required since earlier splitters were not able to pass power. A 2-way power divider was then protected by two ferrite isolators and two DC power blocks. This assembly of six components plus numerous cables and N-connectors had substantial insertion loss and was more prone to installation errors and breakdowns. For example, water could enter at many more places. This whole set of equipment wholesaled for approximately $440; the new single piece of equipment costs half that amount.

Two Block Downconversion Receivers/12 Channels

This system accomplishes the same result as the previous one using a simpler, less costly design. A splitter rated for the block downconversion frequency range (which is usually 950 to 1450 MHz or often 450 to 950 MHz) splits the UHF intermediate frequency signal in two. One side is DC blocked; the master receiver passes DC current to power the LNB. Either the master or any of the slave receivers can independently select 12 channels depending upon which polarity is selected by the master receiver. Slaves are usually lower cost detent tuned receivers.

Similar systems can be designed using any number of slave receivers. All that is required is more splitters and, when required, a line amplifier rated for these high frequencies to boost signal strength. An LNA/block downconversion receiver can also be used in place of the LNB. The only change would be the insertion of one block downconverter at the dish which would be powered by the master receiver. Remember that the master receiver must always be left on unless turning it off does not interupt power to the downconverter/LNA.

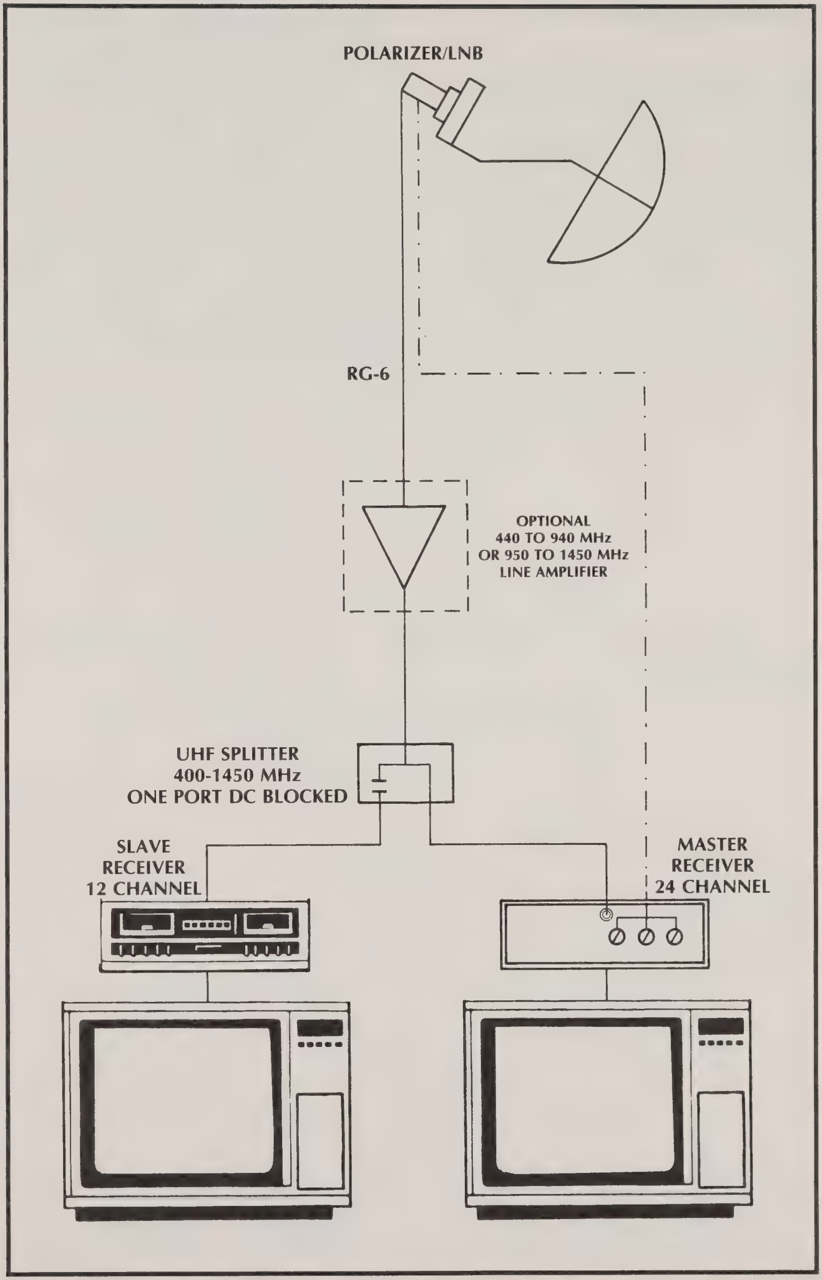


Figure 5-20. Two Block Downconversion Receivers/12 Channels.

One Single and One Block Receiver/12 Channels

Occasionally a customer will already have a single conversion satellite receiver and will want to upgrade to a 12 channel multiple receiver installation using a master block downconversion receiver. The configuration shown here will accomplish this design objective. Also, if a second or more slave block downconversion receivers are desired, this design and the previous one are simply added together resulting in a multiple receiver system having just one single conversion receiver.

High frequency, 2-way splitters pass DC power from only the master block receiver. It may be necessary to use a DC power block to protect the ferrite isolator from drawing power and burning up. An alternative is to disable the DC power coming from the single conversion downconverter. Some receivers such as the Drake, Avcom Com-2 or Gillaspie have an external power jumper on the downconverter which can be cut to disable power to the LNA. Other brands require some surgury inside the downconverter. This involves cutting the correct fine aluminum foil trace or metal channel near the 4 gigaHertz input on the printed circuit board. Great care should be taken in doing this.

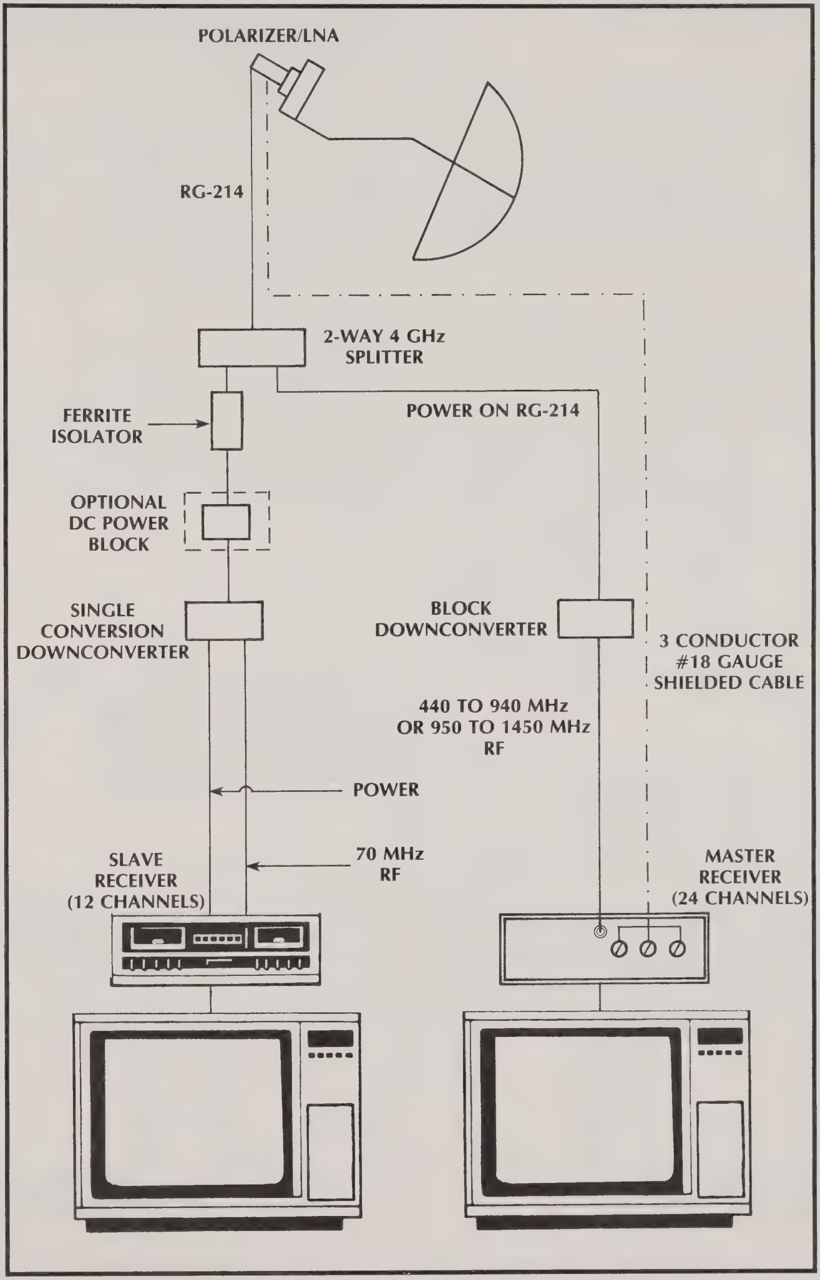


Figure 5-21. One Single and One Block Receiver/12 Channels.

Two Single Conversion Receivers/ 24 Channels

Two receivers each having the capability to independently select 24 channels requires the use of two LNAs, one positioned for vertically and one for horizontally polarized signals. And each receiver must be able to select between either polarity independently of what the other receiver is doing.

To accomplish this objective, a design with two independent blocks is created. The signal generation block consists of the antenna, feed assembly and a network of power dividers having an independent power supply which is always turned on. This feeds horizontally and vertically polarized signals into the second block which consists of as many coaxial relays/ receivers as is required. The DC power at the dish must be blocked from reaching the coaxial relays, so a power divider with DC insertion and blocking is used. Each receiver must be isolated from all others with ferrite isolators. Often DC power blocks are required to protect the ferrite isolators.

In this case, two 2-way power dividers rated for 4 GHz are used to create two sets of complete satellite signals. In a 3 receiver system, two 4-way splitters each having one output port terminated with a 50 ohm terminator would be used. More and more receivers can be added in a similar fashion. Remember that 50 dB LNAs and occasionally line amplifiers rated for C-band frequencies must be used to compensate for signal power losses which occur when the signal is split many times enroute. A 40 dB LNA simply would not provide enough gain to do the job unless beefed up with a line amplifier.

The reason for using a dedicated power supply, not the receiver power supply, is to avoid a situation where turning off the master receiver would cut off power to all the downconverters and LNAs. In addition, if one receiver powered two LNAs and an extra downconverter, enough current might be drawn to blow half ampere fuses or burn out receiver voltage regulators.

Coaxial relays are usually opened or closed by 12 volts DC taken from a rear panel port on the receiver. When signal polarities are flipped in channel selection these voltages automatically change. An alternative is to use an on-off toggle switch which chooses between 12 and 0 volts.

Figure 5-22. Power Supply. *This device provides 15 to 24 volts DC power to the downconverters which are disconnected from receiver power supplies. (Courtesy of DX Communications).*

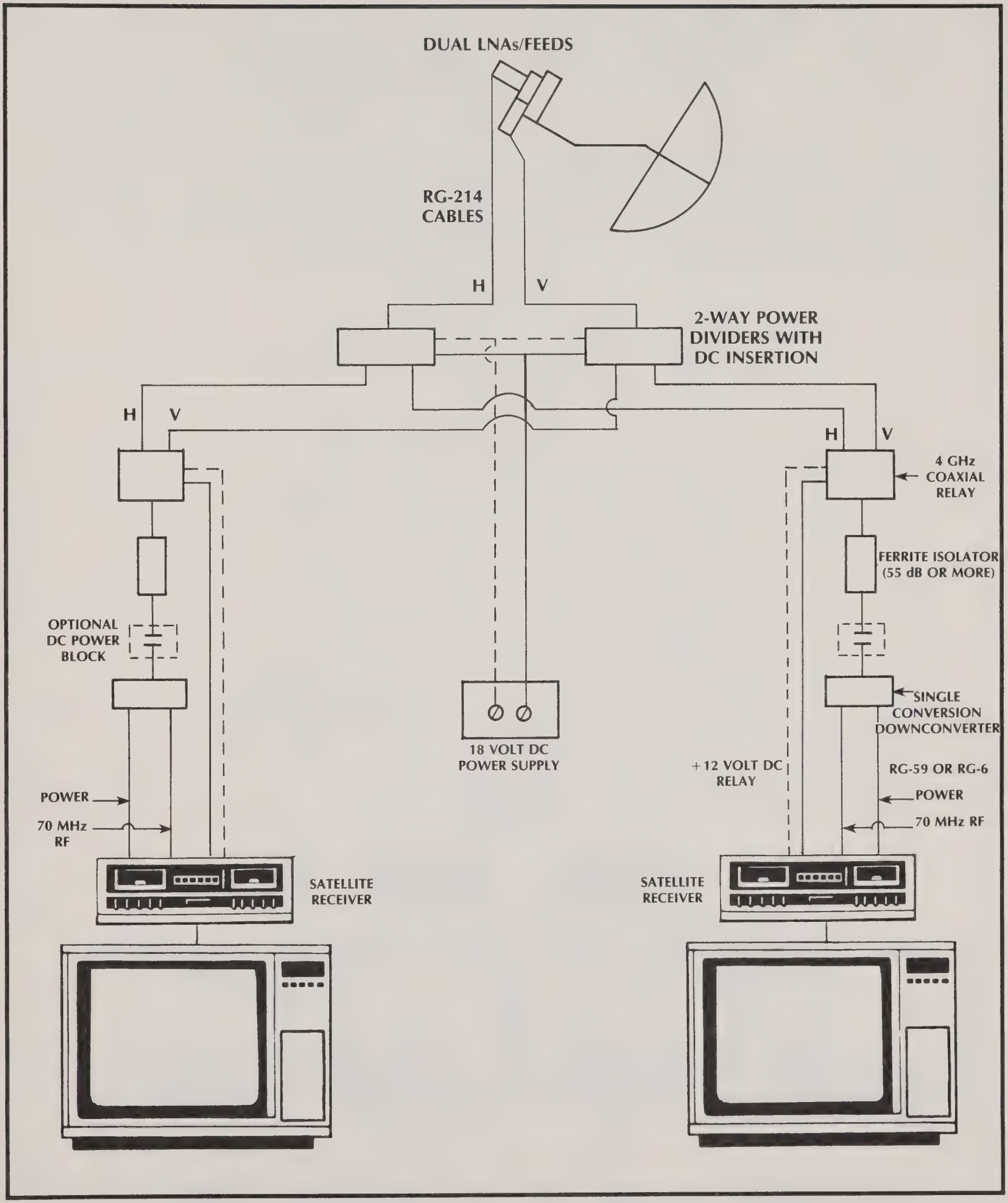


Figure 5-23. Two Single Conversion Receivers/24 Channels.

Two or More Block Receivers/ 24 Channels

M/A COM System

Designing 24 channel independent receiver systems is easier using block downconversion technology because a number of companies sell special "all-in-one-container" components to accomplish all the required splitting, isolation and power blocking functions.

The M/A COM switching matrix system uses dual LNBs to drive multiple receivers. In this case, a 4-way receiver switch is shown. A plus or minus 12 volts DC terminal on the back of M/A COM receivers activates a network of splitters which independently select either horizontally or vertically polarized channels. As a result, all 4 receivers have independent, 24 channel selection.

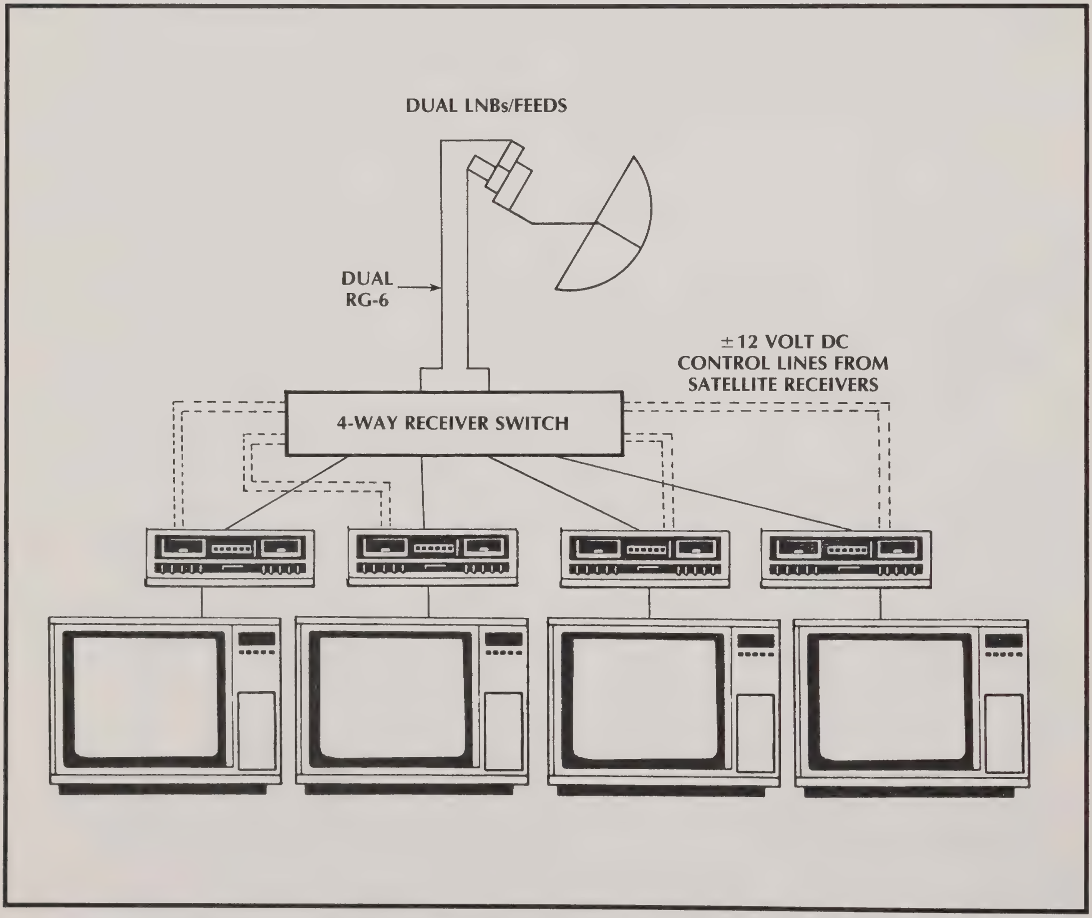


Figure 5-24. Two or More Block Receivers/24 Channels -M/A COM System.

DX System

Two different multiple DX receiver systems are shown here. The first is similar to the single conversion, 24 channel system described earlier. In this case, an optional line amplifier is inserted for extra long cable runs. The second system is designed like multiple-home installations with taps to as many receivers as are necessary. This design is a first step taken when creating more extensive distribution systems used in SMATV systems for apartment complexes, hotels and other multi-room situations.

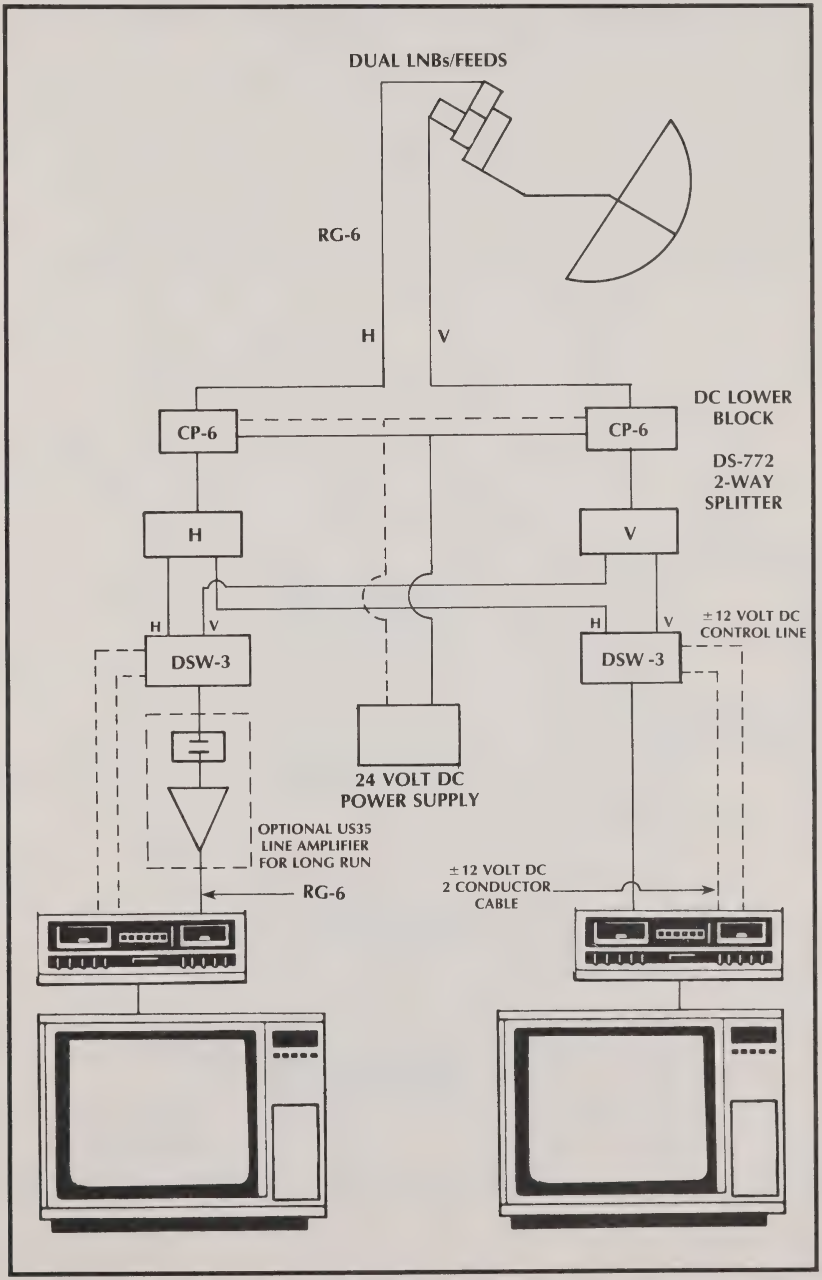
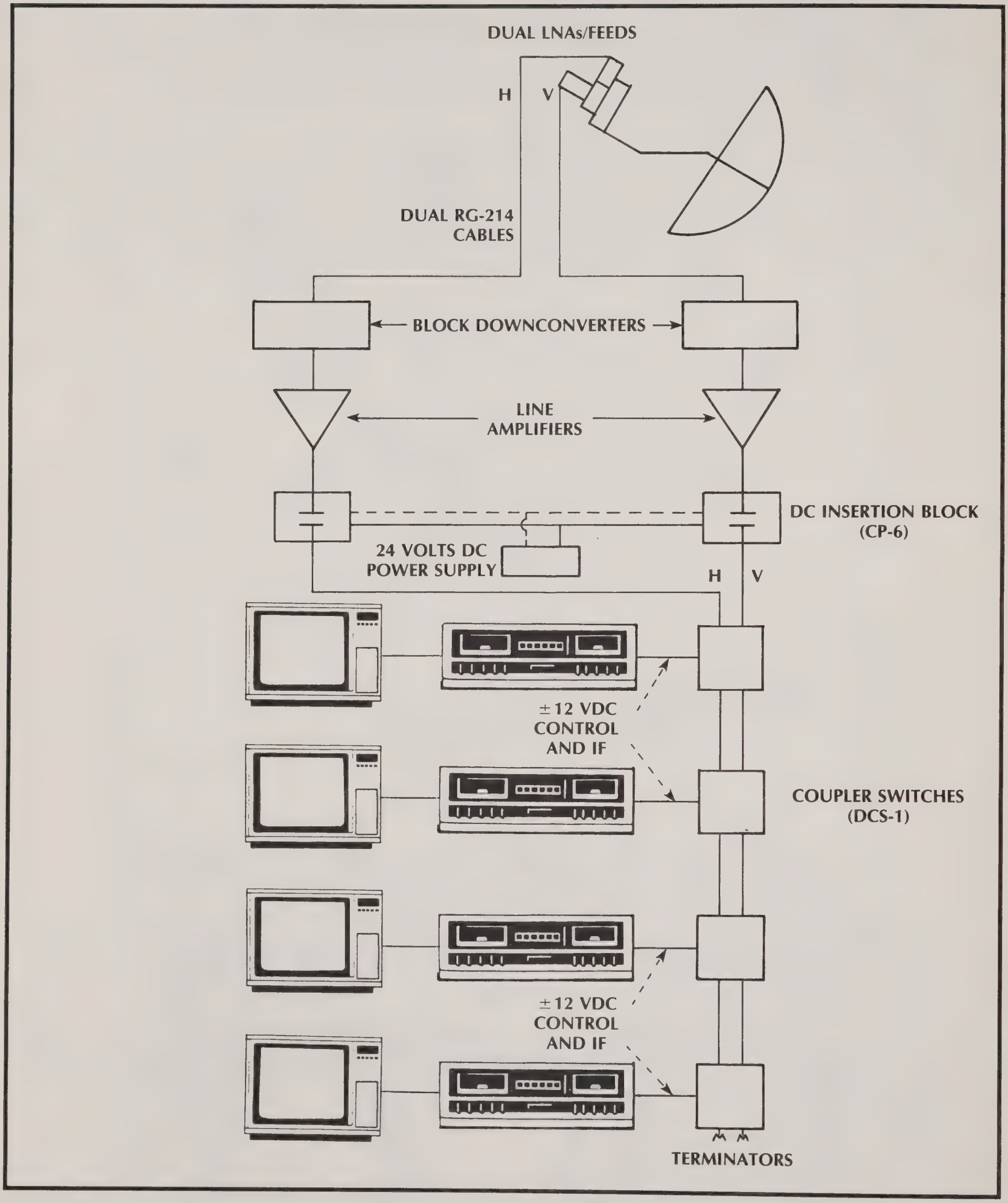


Figure 5-25. Two or More Block Receivers/24 Channels - Two DX Systems.


DUAL LNAs/FEEDS
H
V
DUAL RG-214
CABLES
BLOCK DOWNCONVERTERS
LINE
AMPLIFIERS
DC INSERTION BLOCK
(CP-6)
24 VOLTS DC
POWER SUPPLY
H
V
±12 VDC
CONTROL
AND IF
COUPLER SWITCHES
(DCS-1)
±12 VDC
CONTROL
AND IF
TERMINATORS

Single Receiver/Dual Frequency Bands

This system allows the user to view either C-band or Ku-band broadcasts over the same receiver and TV system. Since both the Ku-band LNB and C-band LNA/downconverter convert to the 900 to 1400 MHz range, the same receiver can process both signals. A power passing A/B switch activates whichever LNB or downconverter/LNA is selected. Companies such as DX and Lowrance make such systems.

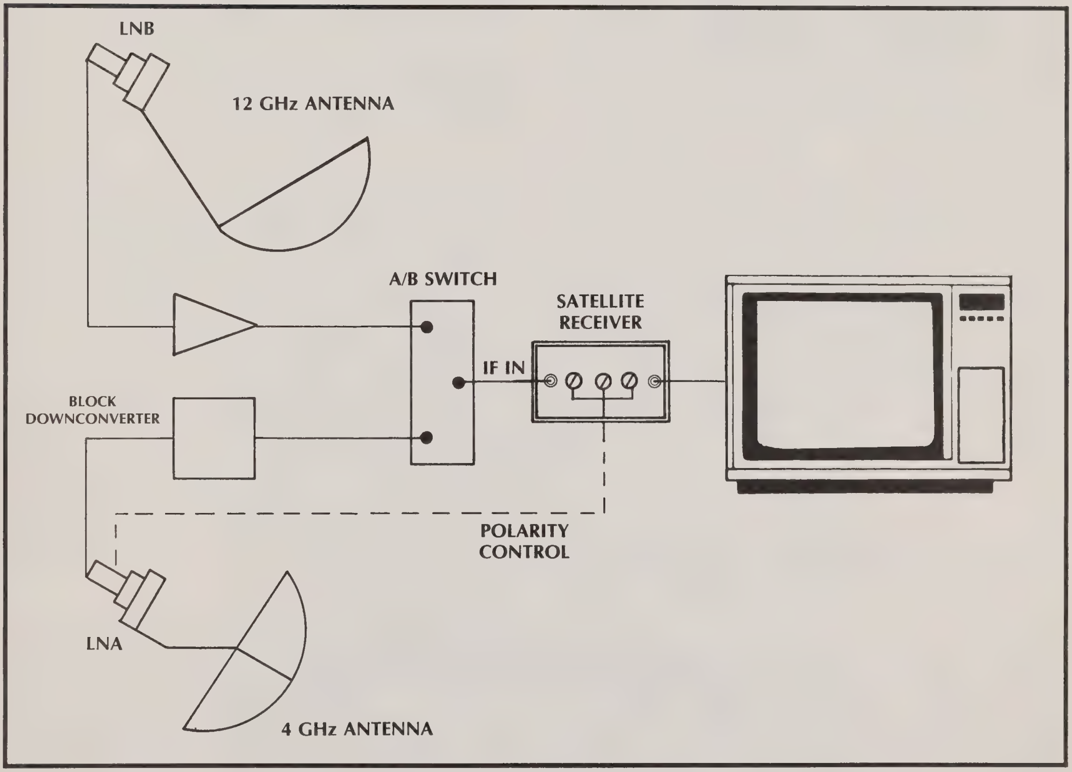


Figure 5-26. Single Receiver/Dual Frequency Bands.

C. SMATV SYSTEMS

The Headend

The objective in designing an SMATV systems is to provide each television set on the network with one or more channels which have sufficient power (0 to 3 dBm) and which do not interfere with each other. At the "headend," signals are captured from the various sources and processed so that all channels will have nearly equal power when combined on the output line. Note that outputs from each receiver configuration outlined above can be used as an input to an SMATV headend.

Note that satellite signals can be captured by any combination of antennas, be they single or multiple focus. Commercial networks often use larger, fixed antenna to deliver a signal many dBs stronger than the receiver's threshold to the headend so there is little possibility of "down time." Commercial systems are usually designed having C/Ns in excess of 15 dB while C/Ns of 11 dB are considered more than adequate for homes satellite TV systems.

The Distribution Network

The distribution network is designed to take this combined output and deliver a balanced, sufficiently strong signal to each television. Master antenna television (MATV) or satellite master antenna systems (SMATV) can be compared to water distribution systems. Without enough pressure in the system, water will just trickle out of shower heads; with too much pressure, pipes can burst and water knocks develop. When receiving television broadcasts, snow can appear from a weak signal and picture flutter or jitter from a overdriven signal.

The Basic Components

An SMATV system is composed of a number of basic components. These include those outlined in section A above as well as modulators, bandpass filters, taps, amplifiers, coax and connectors.

Modulators, Processors and Bandpass Filters

The purpose of a modulator is to "rebroadcast" a television signal from one frequency range/format to another. For example, those modulators which are built into a video receiver take the raw audio and video satellite signal and translate it into a AM format tuned to usually either VHF channels 3 or 4. A commercial grade modulator might convert the satellite TV raw signal to VHF channel 13 or to UHV channel 36. Note that devices called channel converters take one channel and remodulate it onto another. So, for example, a converter might take VHF channel 5 and translate it onto UHF channel 38. These are usually crystal controlled.

Modulators fall into three broad classes. "Home style" modulators which have evolved from home VCR technology usually operate on channels 3 or 4 and have low output powers, typically on the order of 0 to 3 dBm but always lower than 10 dBm. They do not have built-in bandpass filters to limit their output to a narrow frequency range centered on the targeted channel. Commercial modulators have much higher outputs, with typically 20 dB or more of gain. A distinction is drawn between those brands with and without built-in bandpass or SAW (surface acoutical wave) filters. Those not having

bandpass or SAW filters can generate a signal which may interfere with an upper or lower adjacent channel (see below for a discussion of this topic).

Crystal stabliized modulators are permanently set on one channel. Many modulators used in home satellite receivers are crystal stabilized. Usually home satellite TV modulators can be switched beteen channels 3 or 4. Other brands also can often be switched between a different set of channels. Those modulators which are LC (an abbreviation for inductor/capacitor) driven can be tuned by a small set screw across a range of channels. Note that when this adjustment is made (for example, on the Anderson line of receivers) a non-metallic screwdriver is required since metal affects the circuit elements and can make fine tuning onto the selected channel difficult.

Commercial modulators have adjustable audio and video levels as well as RF output level controls. The audio and video settings

Figure 5-27. Bandpass Filter. *This inexpensive bandpass filter is designed to be inserted into a F- connector coax line. This particular one eliminates the lower sideband on UHF channel 6. (Courtesy of Pico Products, Inc.).*

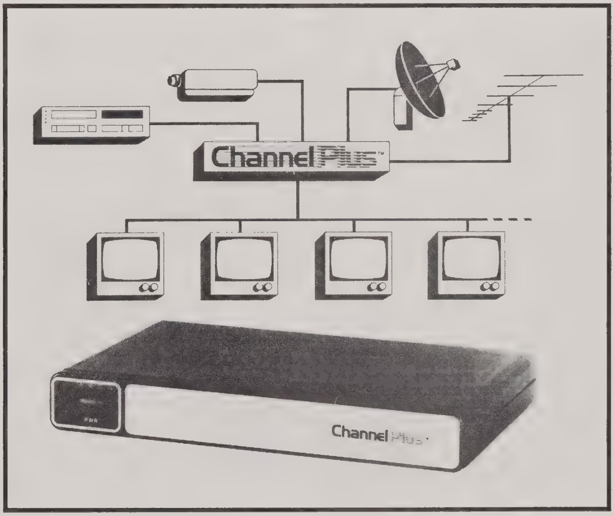


Figure 5-28. A Channel Multiplexor. *The Channel Plus interconnection system accepts baseband or off-air inputs from any source such as a satellite receiver, home video camera, security system, VRC, cable TV or television antenna and translates them onto any group of selected UHF channel on multiple TV sets. (Courtesy of Multiplex Technology, Inc.).*

control the "percentage of modulation" or how much of these signals are added to the carrier. Higher video outputs makes for a brighter television picture but too high a level causes a buzz in the audio and washed out pictures. The RF adjustment sets the output dBm power level.

Channel processors also have outputs which can be combined with signals from modulators. However, processors take already modulated signals usually from off-air broadcasts and "clean up" the signal. They do this by demodulating down to baseband, amplifying and filtering both the input and output signal to eliminate the unwanted sideband. Then the output is remodulated onto the same channel as the input signal.

Taps

A tap, also known as a directional coupler or directional tap, extracts a specified portion of an incoming signal while allowing most power to pass through to its output. For example, a 24 dB tap would take a 30 dBm signal, siphon off 6 dBm (30 less 24 dBm) and pass the remaining portion less a small insertion loss of about 0.5 dB to its output leg. Table 5-3 below shows that the lower the tap value, i.e. the more signal extracted, the higher its insertion loss.

TABLE 5-3. TAPS AND THEIR TYPICAL INSERTION LOSSES

Rated Tap Value (dB)	Insertion Loss (dB)
30	0.5
27	0.5
24	0.5
20	0.5
16	0.8
12	1.0
9	1.5
6	2.2

To iilustrate, a 40 dBm signal would be reduced to 39.5 dBm after passing throught a 24 dB tap but to 37.8 dBm following a 6 dB tap. The first tap would extract 16 dBm of signal;

Figure 5-29. Channel Processor. *This processor is used to add off-air television signals to private cable systems. Internal input and output bandpass filters provide undesired channel rejection and spurious signal attenuation. (Courtesy of Nexus Engineering Corportion).*

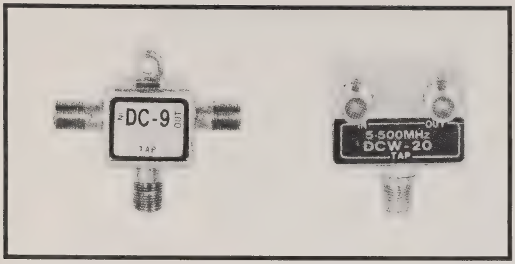


Figure 5-30. Taps. *These two taps are rated for 20 and 9 dB and have maximum insertion losses of 1 and 0.5 dB, respectively. (Courtesy of MACOM Industries).*

the second 34 dBm. Note that a tap differs from a splitter which divides a signal equally into two or more output legs. But both devices are used to accomplish the same function. Taps are usually installed to pull signals off a main feeder line since the throughput losses are much lower. Then splitters are used for local distribution to individual TV set.

Television Channels and Balancing Signals

Whenever signals are modulated onto two adjacent channels there is always the possiblity for interference to occur. The FCC wisely allocated sets of non-adjacent, off-air broadcast channels in each region or metropolitan area of the country. Thus, for example, Denver has channels 2,4,6,7 and 9 in use while Philadelphia area TV stations broadcast over channels 3,6,8,10 and 12. (See below to understand why channels 6 and 7 are not adjacent to each other.).

Today, SMATV systems may be designed to relay, for example, 5 off-air channels along with 4 satellite TV broadcasts onto the VHF television band. Headends therefore process and transmit adjacent channels and must be be designed so each one is received without interference from all others. The UHF band can also be chosen as a target for modulation but cabling losses are higher than in the lower frequency VHF band. Therefore, extensive distribution systems will often be designed to use the VHF range.

Each video broadcast has its video, color and audio information organized as shown in Figure 5-31. If the audio signal power is too high, it can bleed into the upper adjacent channel video and place a cross hatch or pattern over the picture. If the video bandwidth has not been cut off or filtered below the lower channel edge, it can bleed into the lower adjacent channel and cause scratching sounds and "cross-talk" on its audio output. Therefore, whenever adjacent channel modulation is used, two rules must be followed. The signal must be restricted by a bandpass or SAW filter to protect the lower adjacent channel and the audio level must be 15 dB below the upper adjacent video channel.

Table 5-4 shows which channels should be considered adjacent in the VHF band. Since there is a large space between the VHF low band (2 through 6) and VHF upper band channels (7 through 13), channel 6 does not have an upper adjacent and channel 7 does not have a lower adjacent. Note that fortunately for system designers there is also a frequency space between channels 4 and 5, a 4 MHz guard band which is occupied by marine radio communications.

This table has very valuable information for a satellite TV dealer. For example, assume that a small motel wants to send two satellite channels to each room along with its off-air broadcasts. If channels 2,4,7 and 9 are occupied, satellite TV could be modulated onto channels 11 and 13 with no trouble. But what if an off-air station is already relaying a broadcast on channel 11. A good choice would be to modulate the satellite signal onto channel 6 which has no upper adjacent channel as well as onto the free channel 13. This sensible choice would save time and money in designing a headend. Less expensive modulators and signal balancing techniques could be used since non-adjacent channels have been chosen instead of channels 5 and 6.

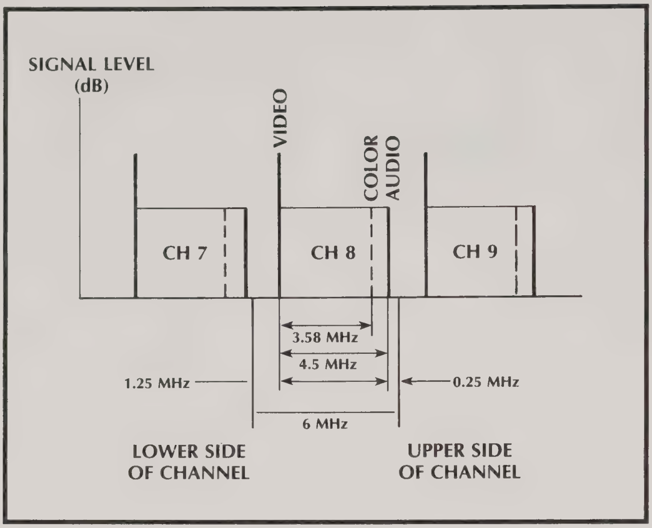


Figure 5-31. Layout of Audio and Video Channel Signals. *Each television channel is organized into a video subcarrier centered 1.25 MHz above the lower side of the channel, a color signal centered 3.58 MHz above the video and an audio signal 0.25 MHz centered below the upper edge of the channel.*

TABLE 5-4. VHF TV CHANNEL ALLOCATIONS

Channel Number	Frequency Range (MHz)	Upper Adjacent	Lower Adjacent
2	54-60	3	none
3	60-66	4	2
4	66-72	none	3
5	76-82	6	none
6	82-88	none	5
	FM Band		
7	174-180	8	none
8	180-186	9	7
9	186-192	10	8
10	192-198	11	9
11	198-204	12	10
12	204-210	13	11
13	210-216	none	12

Note that a precise balancing of signal levels is not nearly as important in systems which do not use adjacent channels. Systems should be designed, if possible, with non-adjacent channels as targets for modulation. When adjacent channels are used, however, high quality modulators which "clean up" the audio and video signal and which provide filtering are a must.

Combining and Distributing the Signal

Once each output from each modulator has been equalized in power level by use of any necessary line amplifiers or by lowering the RF power level and the necessary bandpass filtering and processing has been accomplished, signals can be combined. Note that the signal levels can easily be measured by using a field strength meter. This is an essential tool for any SMATV installer. Levels can also be calculated in advance of installation. For example, if a modulator with 40 dB output is drawing a -3 dBm baseband signal from a satellite receiver, it will provide 37 dBm to the distribution system. If an adjacent channel is being relayed at 32 dBm, in order to set the level of the first to an equal level either a 5 dB pad could be inserted or the RF level adjustment could be lowered by the appropriate amount.

Note that rooms which house headend equipment must be maintained at a relatively constant temperature. Modulator outputs can increase by over 10 dB when temperatures drop from a hot summer day to a cold winter night. Humidity must also be controlled since excessive amounts of water vapor will cause electronic components to degrade.

Signals can be combined by using either splitters or taps in reverse. Thus, for example, a 3-way splitter could take three separate signals and combine them into one stream. Or a network of taps could take signals and add them together. Remember that insertion losses will be the same when using these splitters in a reverse as in a forward direction. Devices called combiners are specially designed for this purpose.

Similarly, two types of distribution systems can be designed using either taps or splitters. In general, splitters are used for smaller systems. Designs ranging from larger SMATV systems to enormous cable TV networks use the trunk line and feeder cable with taps approach. A main trunk line is never tapped but uses only splitters and amplifiers so that the distribution system will be well protected from ingress interference. Then taps are used in feeder lines. For example, if a hotel having two small 5-room buildings was being cabled, a 2-way splitter might be used to feed each building. Then either a splitter or a tap network could be used in each building to feed each of the five rooms.

The objective in designing a distribution system is to provide from 0 to 3 dBm of signal to each television. Once the signal power leaving the headend is known, it is simply a matter of subtraction to calculate the losses at each tap, splitter or pad in each cable run to ascertain that adequate signal reaches each set.

Example of SMATV Headends

Three examples of SMATV headends are illustrated below:

4 Channel Headend

This SMATV headend may be located at a hotel in an area where no off-air TV is available.

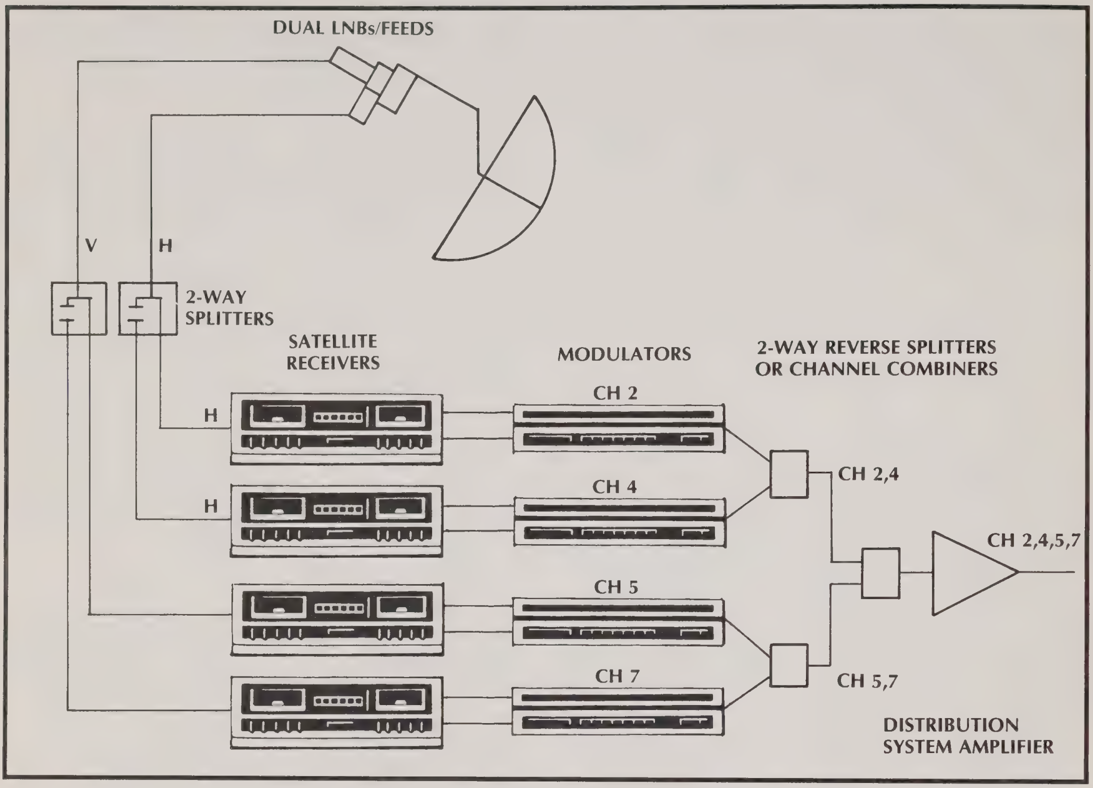


Figure 5-32. SMATV System - 4 Channel Headend.

Four satellite TV channels, two horizontally and two vertically polarized, are being distributed. Note that the even and odd channels from the block downconversion receivers are combined after the modulator in reverse 2-way splitters before being all added together on one line. The system is designed this way to protect adjacent channels from interfering with each other. Note that since channels 4 and 5 ar not adjacent in frequency, lower cost modulators without bandpass filters can probably be used but this is not advised.

7 Channel Headend With Off-Air TV

This 7 channel headend combines four satellite TV channels with 3 off-air stations into one distribution network. In this case, care has to be taken in protecting channels 8 and 9 from interfering with each other by properly balancing signal levels and by using a bandpass filter either as an extra component or built into the channel 9 modulator.

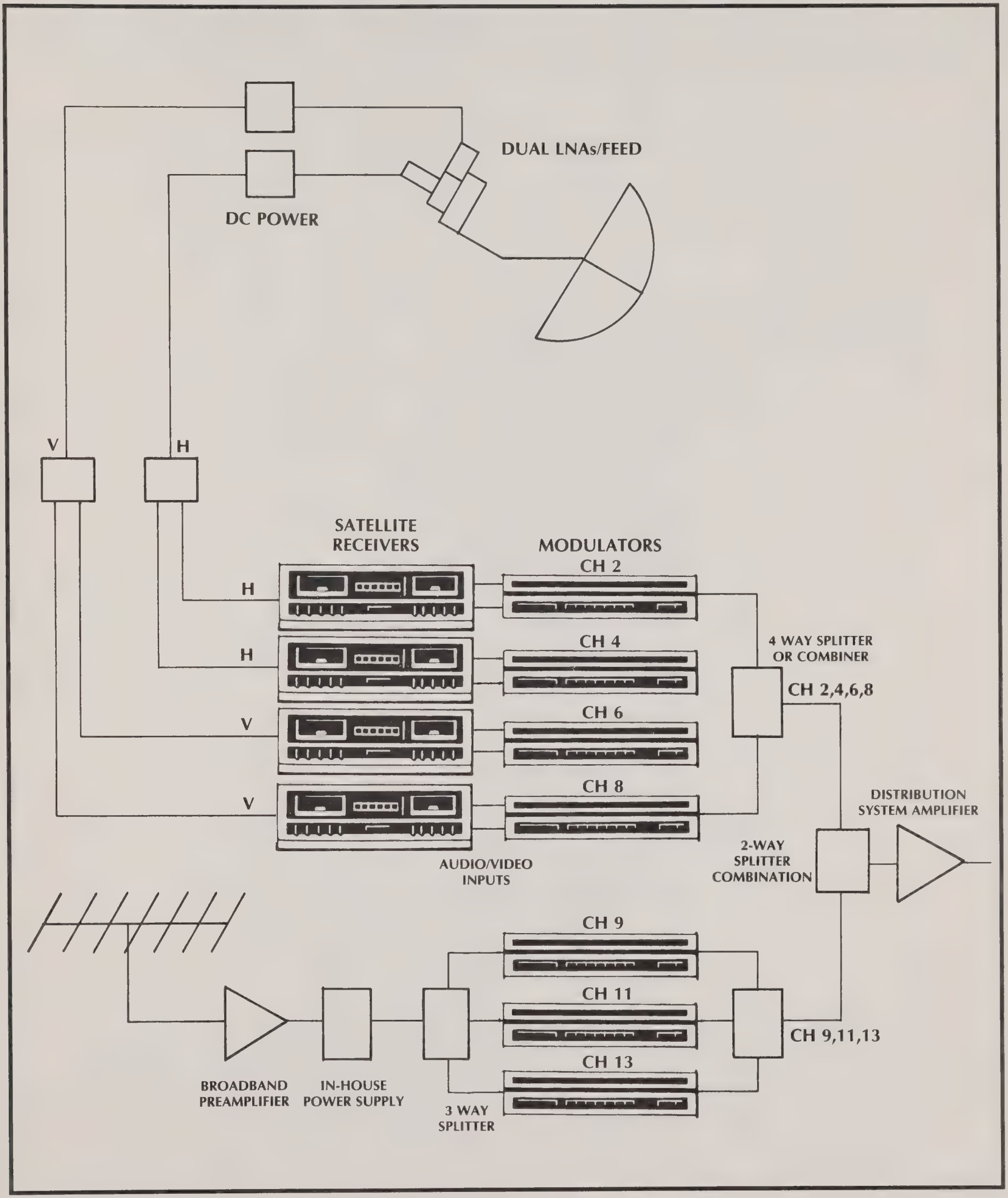


Figure 5-33. SMATV System - 7 Channel Headend.

12 Channel Headend

This 12 channel headend occupies all the available VHF channels. Three 4-way splitters used in reverse, sometimes also labelled as combiners, feed their outputs into 3-way combiners and possibly a line amplifier and subsequently into the distribution network.

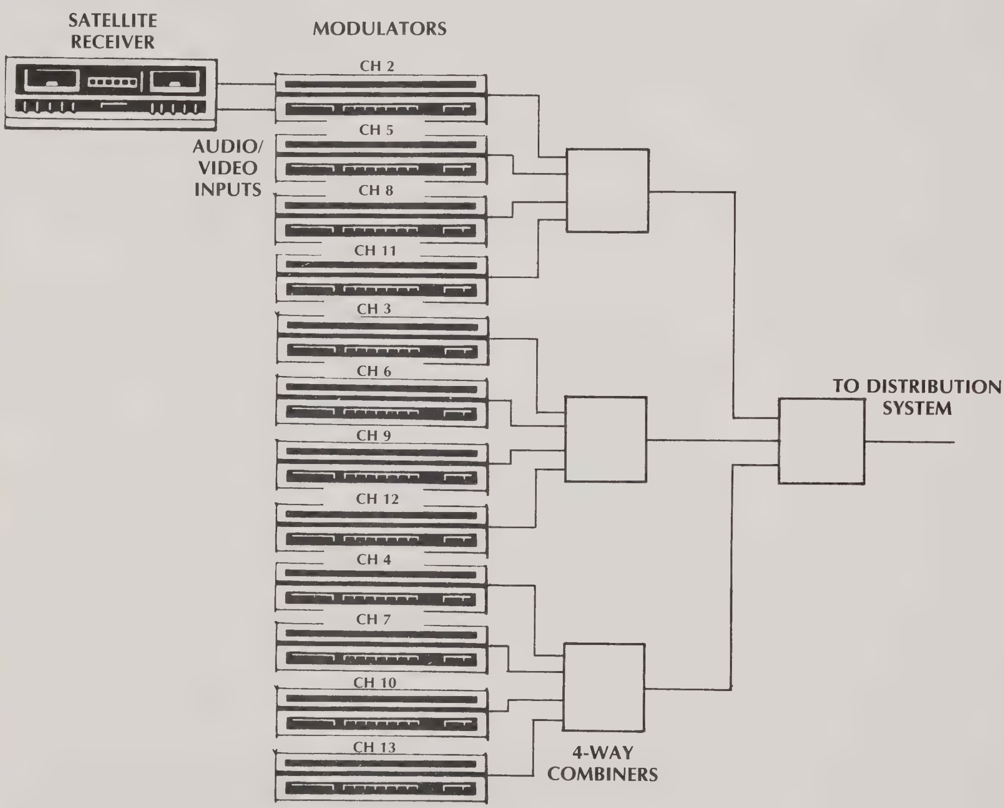


Figure 5-34. SMATV System - 12 Channel Headend.

Examples of Distribution Systems

Two simple distribution systems, one using taps and one using splitters are shown below. These diagrams clearly demonstrate how power levels can be traced to their final destination.

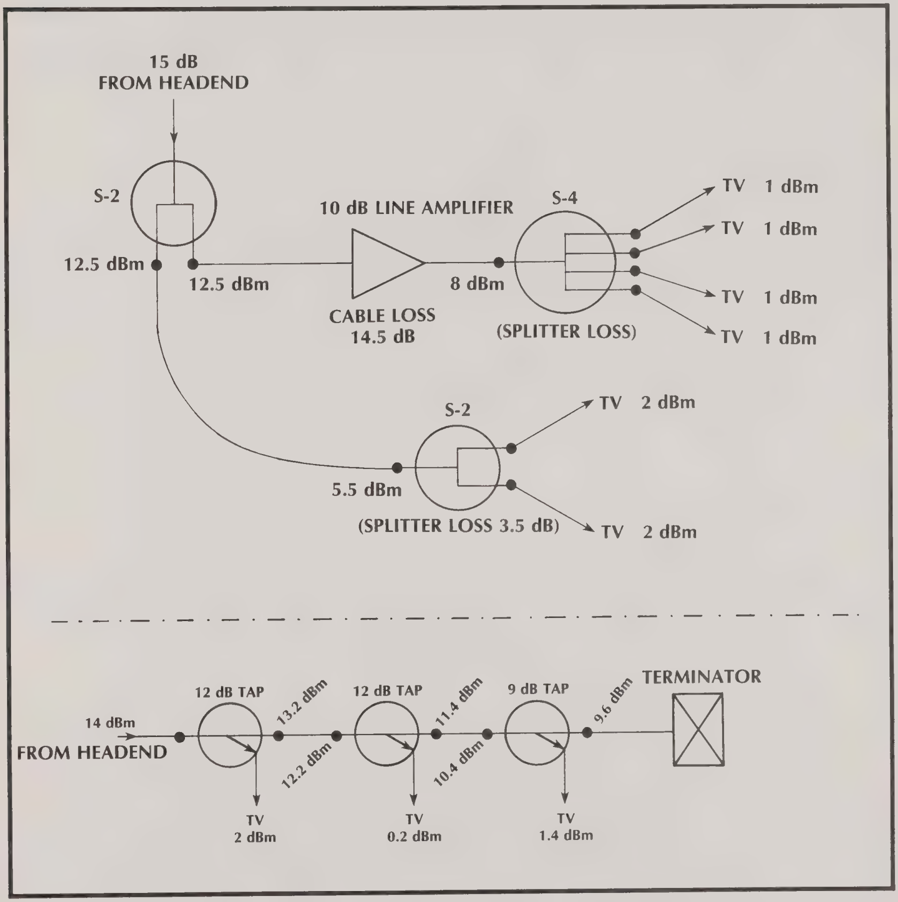


Figure 5-35. Distribution Systems. *These two examples of distribution systems show how power levels are calculated for both tap and splitter networks.*

Figure 5-36. DX Satellite Receivers. *The DX-600 and DX-700 satellite receivers are often used in small commercial systems. In larger SMATV installations, receivers such as these commercial grade DX units are rack mounted at the headend.*

VI. LARGE ANTENNA SYSTEMS

In the earlier days of satellite broadcasting, antennas were most often 15 feet and larger in diameter and were used by cable TV companies and other commercial ventures. As technology has progressed, dish size has decreased dramatically. However, there are still situations where dishes up to 30 or 40 feet in diameter are required. In fact, some dealers who have specialized in these uncommon systems have thrived.

A. WHERE AND WHEN LARGE DISHES ARE NEEDED

There are two main reasons for using large antennas. First, if the installation location is far removed from satellite boresight, the EIRP is so low that an extra large reflector is needed to capture enough signal to drive the receiver. For example, those in Argentina wishing to view American broadcast satellites often require dishes as large as 30 feet in diameter. Or if an earth station designed to receive broadcasts from an Intelsat or European satellite is being installed on the east coast of North or South America, a very large antenna must also be used. In these cases, a 5 meter or 16 foot antenna is generally required for sparklie-free reception.

Second, large antennas are often needed for those commercial installations where signals must be at levels substantially above receiver threshold in order to have perfectly clear reception. Cable TV companies, for example, require video and audio signals whose quality will remain excellent even after being distributed to thousands of subscribers.

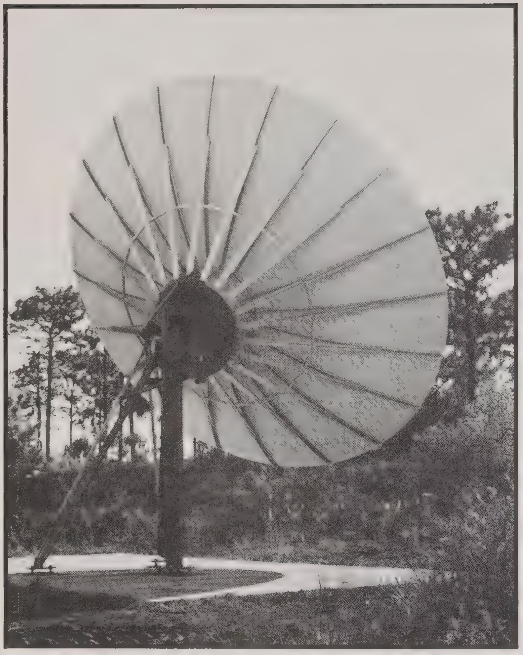


Figure 6-1. Comtech 7.3 Meter Antenna. *This 24 foot is mounted on an adjustable tripod assembly which is supported by a large recessed concrete pad. (Courtesy of Comtech Antenna Corporation).*

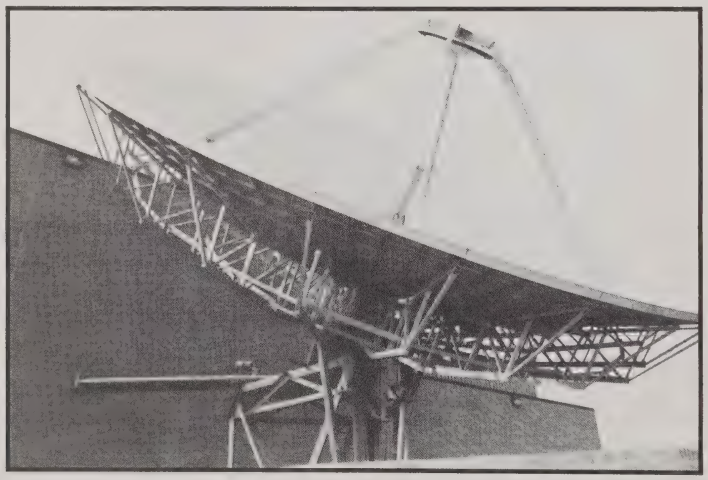


Figure 6-2. Uplink/Downlink. *This 10 meter (33 foot) Cassegrain antenna has a carefully designed rib structure to support the weight of its reflector. This uplink monitors its uplinked signal by also receiving downlinked satellite signals.*

B. INSTALLING LARGE ANTENNA SYSTEMS

Satellite TV earth stations having extra large antennas are similar in many respects to more conventional designs. But there are some major points of difference in their installation.

Mechanical Assembly

A 20 or 30 foot antenna is a very large structure weighting much more than a typical home system. Total dish and mounts weights in excess of 5000 pounds are not uncommon. The supporting structure cannot be simply a pole planted on a small pad or set a few feet into the ground. Excavation is often required before pouring 4 or 5 cubic yards of concrete necessary as a foundation for a double A-frame support.

Heat and sunburn can be a major consideration when large antennas are installed in regions near the equator, as is often the case. Working at the focus of a 30 foot reflector can be more than just uncomfortable if the dish happens to be pointed at the sun. If a fixed antenna is being installed, work in the structure should be planned for those times of day when the sun is far off its main axis. Or, if the antenna can be rotated, it should be positioned away from the sun whenever crews are working in the reflector.

Heavy equipment is often necessary for installation of large dishes. If the antenna is pieced together on the ground, a crane or special hoist is needed for lifting it onto the support-

Figure 6-3. ADM Antenna. *The reflector on this 20 foot dish can reflect enough sunlight to give an installer a severe sunburn. This is especially true because the installation is in tropical Sri Lanka. This antenna, which has not yet had its feed assembly installed, rests on a horizon-to-horizon polar mount. (Courtesy of Antenna Development and Manufacturing, Inc.).*

ing structure. Some antennas, such as the ADM 20-footer or Paraclipse 16-footer can be assembled piece by piece on the mount so the whole reflector does not need to be lifted at once.

Safety of the installation crews is an important consideration. Much of the work is performed far above the ground and very heavy components are involved. The effects of a bright, hot sun should also not be ignored. Protective headgear and shoes should be worn.

Shipping a very large antenna is not simply a matter of having UPS or another freight company deliver 2 or 3 small boxes. Specially designed and often heavy crates must be used. Some manufacturers of 16 foot or larger spun aluminum antennas spend half of their sales revenues just on crating the dish!

Large antennas are manufactured by a number of companies including Antenna Development and Manufacturing (ADM), Hero Communications, Paraclipse, Odom Antennas, Star Dish and Pacific Rim. Systems designed for commercial use are manufactured by Harris and Scientific Atlanta, two of the larger companies serving commercial satellite communications customers.

Electronics

Generally, the electronics used in large antenna installations are quite similar to those used in home systems. But there are some important differences.

If international satellites are being targeted, either a specially designed feedhorn or a modified feedhorn must be used to properly detect

Figure 6-4. ADM Antenna Under Construction. *During construction each stamped aluminum petal was lifted onto and attached to the mount. This is the same antenna is the same 20-footer pictured in Figure 6-3. (Courtesy of Antenna Development and Manufacturing, Inc.).*

Figure 6-5. Hero Antenna in Sri Lanka. *A special crane and scaffolding was necessay to lift this 25 foot Hero antenna into place. It is supported by a combination of pole and pad planted in over 5 cubic yards of concrete. (Courtesy of Hero Communications).*

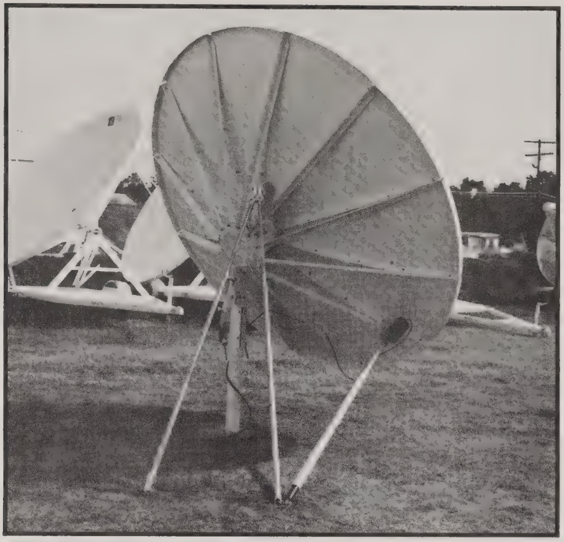


Figure 6-6. Medium Sized ADM Antenna. *A 52 inch actuator arm controls the position of this 13 foot ADM dish. This polar mount is supported by a deeply planted pole and two adjustable telescoping arms. (Courtesy of Antenna Development and Manufacturing, Inc.).*

those signals which are circularly polarized. A teflon dielectric slab inserted into the feed throat permits a conventional feedhorn to receive signals having this different polarization format.

Although the f/D of large antennas also ranges between approximately 0.3 and 0.4, antenna diameter is much larger than normally encountered, so the feed assembly can be at a substantial distance from the reflector. Either a tripod or a buttonhook supported by guy wires must be used to prevent excessive movement in winds or when the dish is moved across the arc. But few large antenna designs incorporate buttonhooks.

If video formats other than NTSC are being used, slightly different receiver electronics are often required. For example, Avcom receivers can be ordered having a special deemphasis circuit for deciphering PAL formated broadcasts as well as a dual IF bandwidth for half or full transponder viewing. Half transponder formats, usually transmitted with circular polarization, use half of the full 36 MHz bandwidth for relaying two TV broadcasts per transponder.

Electonic components should be tested before they are installed in their final position. Once a feedhorn and LNA are in place, replacement often involves a fair amount of effort such as using a cherrypicker to reach the focus. After all components are installed, a portable signal simulator such as the Newton GBS 1600 should be used before attempting to track satellites to make sure that there are no loose cables or other unexpected problems. This is especially important because large antennas often have very narrow beamwidths and are used in loca-

tions where satellite EIRP is very low. In many international locations finding a target is even more trying because there are only a handful of satellites which have transponders active all the time. Tracking the arc can be difficult enough without having to worry about a loose connector or a faulty component.

When doing international installations always have spare parts on hand. It is easier to ship two components and return with one than to fight with customs officials in sending a replacement at a later time. It is highly recommended that all components be tested and burned in for at least 48 hours prior to shipment. Also, an export lisence is required to move many types of microwave components from North American to other parts of the world because they can sometimes be used in defense systems. All special tools or test instruments which may be required should be taken on the trip. Remember that Radio Shacks do not have outlets in Bogata, Columbia.

Figure 6-7. Arthur C. Clarke's Antenna. *A 16 foot Paraclipse antenna was installed by one of the authors at Arthur C. Clarke's home in Sri Lanka. The small tower support was firmly bolted into the structural beams under the floor of this patio. (Courtesy of Paraclipse, Inc. and Arthur C. Clarke).*

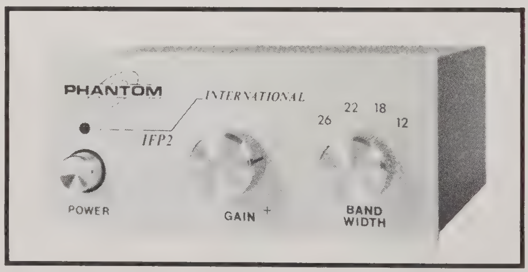


Figure 6-8. Filter for Half Transponder Broadcasts. *The Phantom IFP-2 filter is switchable onto 26, 22, 18 and 14 MHz bandwidths. Half transponder broadcasts which occupy less than 18 MHz of bandwidth centered on a 70 MHz IF could possibly use the 12 MHz setting to reduce sparklies at the expense of picture fidelity. The gain control varies output over a range from 9 dB attenuation to 12 dB gain. (Courtesy of Phantom Engineering).*

Figure 6-9. Maneuvering a Large Antenna. *Five men and one observer were needed to lift this 4-piece, 16 foot antenna into its final position. Using a crane was difficult ontop of this five storey building in Jerusalem.*

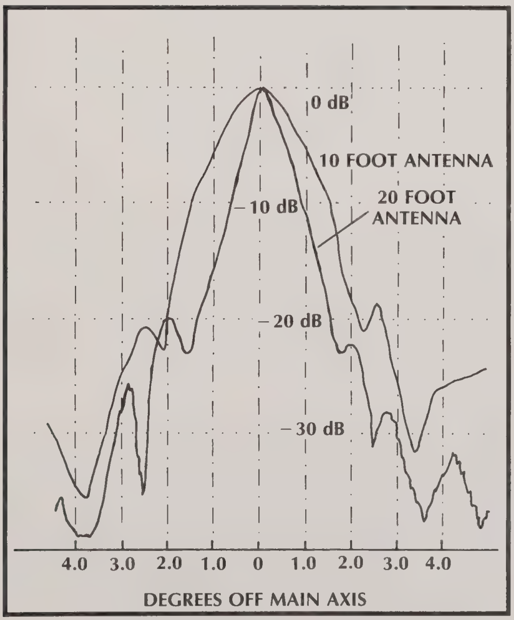


Figure 6-10. Beamwidth Diagram Comparison. *The measured beamwidth of the 20 foot ADM antenna at 1.0 degrees is nearly half that of 1.9 degrees measured for their 10-footer. The larger dish also a 10 dB drop off in detected power at 1.5 degrees compared to 3.1 degrees for the smaller one. This diagram clearly shows why aiming a larger antenna is more difficult. (Courtesy of Antenna Development and Manufacturing Company).*

VII. TROUBLESHOOTING

A. INTRODUCTION

Every satellite TV system will eventually have operational problems. No man-made device lasts forever. However, some systems will have problems sooner than others. A competent dealer will expect this to happen and will factor service and repair calls into his price. Of course, properly selecting equipment in the first place will minimize the probability of breakdowns. But realize that it is not unusual for the minimum cost for a service call to be at least $100. This includes the time necessary to drive out to a site, wear and tear on the service vehicle, the cost of gas and just one hour at $30 or $40 per hour. Service is not inexpensive.

All problems can be solved by thoughtful troubleshooting. The purpose of this section is to provide a consistent method to understand and solve system difficulties in the minimal amount of time. Finding out what is wrong can be an interesting and rewarding exercise if the correct approach is followed.

Troubleshooting can be relatively easy if one component of a once-working system goes bad. This usually happens not long after an installation. It is even easier if the same dealer making the service call had correctly installed the system in the first place. Then he or she will probably have all the necessary documentation to quickly track down the fault. If someone else had done the installation this may not be the case. Some outrageous mistakes have been uncovered when servicing a satellite system which was poorly installed by another.

But often over a longer period of time several little problems can cause pictures to go bad. For example, connectors can corrode, concrete may settle and throw a pole slightly off from vertical, a center conductor in a coax may contract a little and not make perfect contact, the dish may have sagged slightly or shifted off from its north/south alignment, or the feed may have moved noticeably over time. Finally, the customer may call in and complain about having poor reception.

Troubleshooting during an installation can be much more difficult, especially if proper procedures have not been followed from the start. These "proper procedures" are very important to avoid future headaches. For example, let us assume that Joe Lazy has not done a site check and has not tested out the components before installation. Assume that this particular installation had problems with moderate levels of TI, a cable which had already been planted and covered up was shorted and a bad LNA had

been purchased. The bad LNA would have easily been located if it had been tested before installation. Even if this were not the case, if TI had been avoided and a test at the dish with a short cable had been done during installation, the bad LNA and then the shorted cable would probably have been quickly discovered. But once the installation is completed, trying to isolate three problems at once could be rather tricky without going back to square zero.

We assume that the reader has read and understood all the previous material on theory, equipment selection and installation. If so, the procedures below should be easily understood and clear to follow.

Be aware that as the number of installed systems continues to grow and as equipment in the field ages, the troubleshooter's role can only become more important and more lucrative. The hallmark of a successsful troubleshooter will be an approach that combines technical knowledge with a systematic and methodical process for identifying, diagnosing and isolating, and repairing satellite TV service problems.

B. THE BASIC APPROACH

When a customer calls in a problem, a dealer should first try to find a solution over the telephone by conducting a well thought out interview to define all the symptoms. If this does not work, a site visit to the customer's home will be required for a visual inspection of the system. This is the first step in resorting to more technical trouble shooting procedures.

The telephone interview is especially important if a site visit is necessary. It will define what type of repair equipment should be taken. For example, if the customer was out tilling his garden when the satellite system stopped working, certainly bring some extra cable and connectors. There is nothing worse than driving out to a site only having to return to the shop for one small forgotten component like an extra fuse or voltage regulator.

None of these procedures are magical. All that is required is knowledge of how a satellite TV system works and a clear, level-headed approach. No problem is too difficult to solve. And as your experience grows the solutions will come more and more quickly.

Subsystems Approach

Every satellite TV system can be broken done into three subsystems: the mechanical consisting of the mount, dish, feed support and feedhorn; the electromechanical consisting of the actuator and the polarity selection device; and the RF consisting of the LNA, downconverter, receiver, modulator and TV. Each of these systems can be diagnosed somewhat independently even though symptoms may be similar in nature. These three systems are being isolated to simplify troubleshooting procedures.

TABLE 7-1. SATELLITE TV SUBSYSTEMS

Mechanical	Electromechanical	RF
Mount	Actuator	LNA
Dish	Polarity Selector	Downconverter
Feed Support		Modulator/Receiver
Feedhorn		Television Set

The Initial Telephone Conversation and Interview

A telephone conversation between the customer and an experienced dealer can often solve problems and eliminate the need for a service call. This is especially true during the initial few weeks or months of ownership when customers are not familiar with many aspects of their systems. Troubles can range from something as simple as not leaving their television on channel 3 to being unfamiliar with operation of a hand-held remote or not knowing how to tune the stereo processor to the correct subcarriers.

This conversation can also be used to identify symptoms of a problem which may require a service call. Such information can prove extremely useful in making an initial diagnosis about where the trouble may lie and in being ready with the proper equipment to isolate and repair the system. Hopefully, the correct documentation about this installation had been filed away so questions are guided by knowledge about this particular system. The documentation should have included information about dish size, the location of cable runs, the type of electonics installed and other factors as outlined in Chapter IV.

A person who has just purchased satellite TV will probably be very aware of how it should operate and certainly will notice any problems or irregularities which have arisen. Of course, poor picture quality is the most often heard complaint.

An interview is an important first step before anything else is done. Some sample questions are:

- When did the trouble first start?
- Was it a gradual change or a sudden occurance?
- Describe the problems.
- Are these difficulties constant or do they occur at regular or irregular periods during the day or night?
- Was the equipment recently moved or has any component been replaced.
- Which channels and how many channels are coming in clearly?
- Can you receive all the satellites?
- Does the dish move easily from satellite to satellite?
- Have you possibly cut or disconnected any cables by mistake?
- Does the picture quality vary from channel to channel or from satellite to satellite.
- Is the audio or video most effected?
- Are you aware of any large towers having antennas being recently constructed nearby.
- Did it first occur after a storm?
- Do your problems occur more during rainstorms than clear days or more during hot than during cold weather?

- Is it possible that a fuse has been blown in the receiver? Do the lights come on? Could a circuit breaker in the house providing power to the receiver have been tripped?
- Are there any children playing around the dish?
- Was a garden recently dug?

A competent troubleshooter is like a doctor. The patient often knows what is wrong but simply does not have the vocabulary to express it. A well conducted interview will gather useful and important information. Over time you should create a complete list of questions so such an interview will proceed smoothly.

Many problems can be quickly solved by this technique. For example, a customer may complain that pictures are perfect expect during the afternoon. Then, even though most channels have excellent pictures, some are covered with sparklies. We can safely guess that the source is TI since microwave telephone traffic is usually heavier in the afternoon and on weekends. So a simple notch filter may solve the difficulty. Or if every transponder went bad after a severe lightening storm, the cause could likely be a LNA with a blown stage.

Also, for example, if the picture becomes poor during a rain or snow storm, a wet connector or leaky gasket between the feedhorn and LNA may be at fault. This problem could certainly occur more easily if the dish were undersized.

Then there are occasional satellite problems or sun outages which happen infrequently enough that people forget that they are even possible. Sun outages occur twice a year during the spring and fall equinoxes when the sun lines up directly behind the targeted satellite and its RF radiation completely overpowers the broadcast for twenty to thiry minutes. Some dealers are simply not aware of these occurrences. It is therefore also wise to have a first hand acquaintance with satellite TV by having a operational system for comparison purposes.

C. VISUAL INSPECTION

Following a customer interview and a thoughtful evaluation of the facts assembled, a visual inspection should be completed. This is especially important if this installation was done by another dealer.

The visual inspection can be guided by symptoms of the problem. For example, if the customer reports that he can receive television from only one satellite, the first step would be to check the actuator and its control box to see if the dish is stuck in one position. If all channels are coming in with crystal clarity on some satellites but poorly on others, the first visual check will be to determine if the dish is warped on the mount or if the feed is moving off the focal point as satellites are being tracked.

It is important to realize that many symptoms can arise from the same problem. It is easier to do a visual inspection first when a not-so-obvious symptom is encountered than to jump into a more technical troubleshooting approach or to immediately start exchanging components. But symptoms will usually give an indication of where to start the visual inspection. For example, if a poor quality picture were received, it would make sense to first try moving the dish east and west with the actuator or a hand crank than to start measuring voltages. A second sensible step would be to check for loose or corroded connectors and a third one would be to check that the feed is properly centered and the dish correctly aligned. Perhaps the dish has rotated in a strong wind

because the bolts on the collar were not secured tightly or pinned. Sight with a compass to be sure that the polar mount is still properly oriented.

The questions below show the thought process underlying a simple, visual inspection. Many more questions which can be asked will become evident below. The following sections outline some more detailed troubleshooting methods if the simpler ones do not suggest an immediate solution.

Figure 7-1. A Dish Having an Obstructed View. *This antenna is located in the middle of a dense jungle. Although it may not have been completely screened during the winter when the surrounding trees had no foliage, chances are excellent that few satellites in the arc can now be clearly received.*

RF Subsystem

In general, visual inspection will begin at the system control center, the receiver/television. Turn on the TV and what do you see?

1. Does the television work properly on regular off-air channels?

2. Is the picture completely snowy or covered with "bug-fight" sparklies? If there is a weak picture in the background maybe the satellite is not being targeted properly?

3. Is the receiver on and are all the indicator lights working? Maybe a fuse has been blown internally or a 120 volt circuit breaker in the house has been tripped.

4. Is the television tuned to channel 3 or 4?

5. Have any cables behind the receiver been disturbed? Perhaps the RG-6 or RG-59 coax had been crimped improperly and the cable is simply disconnected.

6. Are any other wires loose or disconnected? If this is a new installation make sure that all the wires are well connected to the proper place before powering on.

7. Is there a high signal strength meter indication but no picture. This suggests that the modulator may be bad, that TI may be present or that the TV set is not tuned to the right channel.

8. Is the receiver shutting off because it is overheating? Most receivers have ventilation slots to allow cooling by natural air flow. If heat is not carried away most often the voltage regulator which generates substantial heat is internally compensating and shutting down.

9. Are all the cable runs intact? Check all the cable routes from in-doors to the dish. Perhaps some over-enthusiastic gardener has severed

the cable with a weed-eater, shovel or lawnmower. Maybe a dog chewed through the cable.

10. Are all the connections at the dish secure? Make sure that all connectors are tight and that no water has entered them. Are drip loops installed in the correct places? Maybe a connector on the pigtail or downconverter has corroded. When a cable is used to carry power, water entry can cause corrosion similar to the built-up that happens on a car battery terminal. Cut the cable back and install a new connector past the point where the corrosion ends. Make sure that coax sealant has been used. Clear any suspected connectors with a solvent like carbon tetrachloride, dry thoroughly, and reseal. Also, if a defective pigtail has a slightly short center conductor it may work fine until cold weather arrives and then as this leads shrinks contact is broken (called center connector suckout). If the center conductor is too long, when inserted in the LNA or downconverter it may split the shroud on the center pin and cause it to short out against the inner connector wall.

11. If an LNA/feed cover has not been used, check to see if any water may be sitting in one of the waveguides. If a polarity selection device has been used with the right angle waveguide fitting, water may have collected and a cure might be to drill a small 1/16 ir 1/32 inch drain hole on the underside. Maybe the gaskets between the various flanges have been omitted to further worsen the problem.

12. Does the system work intermittently? Sometimes a bad LNA will function only when it is cooled down to the point where its gain increases. A test for this is to use a hair drier to warm it up on a cold day to check for this malfunction or to use a can of freeze spray on a warm day to bring it back to life.

If there is a possibility of a new local source of TI, it may be wise to bring a small test system and do a quick site check. Alternatively, a notch or bandpass filter may be inserted into the system in an attempt to improve picture quality. Or a spectrum analyser may be used to get definitive proof of interference.

Electromechanical Subsystem

1. Does the dish move when the actuator is used? Maybe a voltage transient from a nearby lightning hit fried the Hall effect, Reed switch or optical feedback sensors. If shielded cable was not used for the sensor leads, the actuator controller may be miscounting and aiming the dish incorrectly. Possibly water has entered the arm and has rusted or frozen the internal assembly so that it does not move any more.

2. Make sure that the motor is pointed up so that the drain holes are pointed down. If there are no drain holes, drill some. Maybe the gasket between the motor cover and housing has been omitted?

3. Is the actuator tube bent or is there wear or scoring on the inner tube? Perhaps the original installer did not install ball joints on the actuator arm supports in order to prevent lateral force on the tube. Maybe he did not set both mechanical and electrical limits to prevent bending.

4. Is the polarity control knob having any effect on picture quality? If it is a mechanical device, is the probe moving when channels are changed or when the skew adjustment is altered? Check to see if obstructions caused by moisture collection, birds or even wasps are interfering with signal reception in the throat of the feedhorn.

5. Is the skew adjustment having little or no effect? Maybe the probe has been bent or mechanically distorted by freezing and thawing water. Make sure that the waterproofing was done correctly with gaskets.

6. Is the probe motor bad? Have a spare handheld controller because the 555 timer in the actuator controller or receiver may be at fault, not the motor.

7. Is the motor servohunting? This can cause hum bars. Have a 10 volt DC, 1000 microfarad

electrolytic capacitor on hand and install it on the polarotor motor at the antenna. Also, check that the wire feeding the motor is thick enough and of sufficient gauge to avoid this problem (see below for more details).

Mechanical Subsystem

1. Does the dish look as if it is mounted correctly and that all the angles are still set properly? If the dish is facing north you have certainly identified the problem. The collar was not tighened down properly and should have been bolted.

2. Has the concrete shifted or settled under the pole or pad so that the pole is no longer level or plumb?

3.When using fiberglass antennas, perhaps the surface of the dish has delaminated or is blistering resulting in poor quality reception.

4. Has the owner painted the dish with a roughly applied metallic paint and therefore affected its surface? Or maybe he has applied a highly reflective paint which is overheating the components at the focus.

5. Shake the dish and check for loose nuts and bolts. Note that this should be done from the outer rim to get maximum leverage. Maybe the installer did not use lock washers or lock-tight and the wind had gradually loosened up the assembly.

6. Are any nuts or bolts missing?

7. Is there excessive wear at any attachment points? Scoring on the support pipe caused by such movement may be a telltale sign. If this is the problem you may want to set a bolt through the outer to the inner pipe when all the readjustments are completed. This will maintain a true north/south tracking axis.

8. Is the dish warped? When you sight along one lip does the other side line up perfectly parallel (see Figure 4-57)? Do the two or three string test, if necessary, to check for warpage. Maybe the mount support was not designed properly and the reflective surface has twisted.

9. Is the feed system secured and centered? This can be checked with a focal finder (see Figure 4-67) or with a tape measure. A loose feed could possibly move in a wind or be jarred out of place as the dish rotates across the arc.

10. Is the feed opening free of bugs or wasps nests? A quick visual inspection will eliminate this possibility.

11. Does the actuator jack have free movement across the whole belt of satellites?

D. TECHNICAL TROUBLESHOOTING

If the initial visual inspection does not provide a solution to the problem, then more technical and direct approaches can be taken. There are a number of ways to arrive at the same conclusion. Pick those with which you feel most comfortable. Troubleshooting has its share of personal touch and intuitive methods.

Switching Components

The simplest method to troubleshoot a satellite system is to switch out components. Thus, if the LNA may be bad, substitute one that is known to be working and see what happens.

Whenever any component is changed always be sure that the power is turned off and the receiver is unplugged to avoid causing further damage. Some brands of receivers continue to send voltages to the system even when the power switch is off. Note that if a good receiver is substituted for the faulty one be sure that its matching downconverter is also used.

This method is direct but can be somewhat time-consuming. Also, if switching components is attempted during a new installation and more than one component happens to be bad, it may prove to be a frustrating attempt.

Interchanging or shotgunning components is used mainly to diagnose problems in the RF system. It is easy to check if the actuator or polarity selection device is not functioning properly by visual inspection and then to find the problem by voltage checks and by other troubleshooting methods.

Voltage Checking

A small, inexpensive voltmeter is an invaluable tool in troubleshooting. A faulty component can be rapidly identified by tracing voltages.

When examining an RF problem, all voltage checking should begin at the receiver. It is the brains of a satellite system and it: powers the LNA, downconverter, polarity rotation device and modulator; selects channels by sending a correct voltage to the downconverter; and communicates polarity, channel selection and audio format information to the user.

The video receiver sends approximately 15 to 24 volts DC to the downconverter and subsequently to the LNA or LNB. If this power does not reach its destination for one reason or another the system will not function.

The first step is to check voltage levels at the receiver. The voltmeter is set on a 20 to 50 DC volts range, whichever is appropriate. (Note that when voltages are measured on the actuator circuit, a 50 volt DC range must be used because an output of 36 volts is common. If not, the reading will be pushed off scale.) The red lead is connected to power and black to ground. If no voltage or a low voltage is measured at the rear of the receiver, then turn it off. Unplug it, disconnect the cable which carries power to the downconverter and take a second voltage reading after powering back on. If the proper reading is obtained there is a short in the system upstream towards the dish. If the volt meter still reads zero or near zero, 99% of the time an internal fuse or a voltage regulator is blown in the receiver.

Always carry extra fuses and voltage regulators. For 50 cents a piece standard 7812, 7815, 7912 or 7915 regulators for the receiver or 7805 regulators for the polarity rotation control can be purchased at electronic supply stores like Radio Shack. Note that the 78-hundred series of regulators have a positive output voltage; the 79-hundred series a negative voltage. Have an extra 555 timer chip used to send timing pulses to the Polarotor® I. These can easily be soldered into a receiver in the field saving many hours of travel time. 555 timers are 8-pin chips which look like a small centipede. They control the position of the internal probe.

Note that voltages can easily be measured on those receivers having barrier strips to which power wires are attached. Some units send the power down the coax with the RF signal. In these cases, voltage must be read between the central conductor and ground. In order to take this voltage reading with the cable connected, insert a 2-way DC passive splitter and measure voltage from the opened splitter lead. Remember, do not leave the splitter in the line because 3.5 dB will be lost by its insertion. An opened port is also an invitation to ingress interference and causes signal losses because of reflection at this discontinuity.

Note also that whenever leads are disconnected or connected the receiver should be un-

plugged. You do not want to inadvertently destroy a good component during the troubleshooting procedure. Just because the receiver is turned off does not mean that power is not being sent to the system.

Let us now assume that the disconnected receiver was delivering full power, but when connected to the cable the voltage was unduely low. There is probably a short or a bad component further upstream towards the dish. Unplug the receiver and disconnect power to the downconverter at the dish. Then replug and turn the receiver back on. If full voltage is measured in the disconnected cable at the downconverter end, the fault lies in the components including the LNA, pigtail or downconverter. If no voltage is measured, then there is certainly a shorted connection somewhere in the power cable. A connector might be shorted or the cable could be crushed somewhere along its length.

If full voltage had been measured in the previous step, reconnect the cable to the downconverter output. Then disconnect the pigtail from the downconverter input and take a reading at this point. Zero or near zero voltage indicates either that the downconverter is faulty or that the cable between the receiver and downconverter has a corroded connector with an excessively high resistance. This latter fault would cause voltage to be lost before it ever reached the downconverter. Downconverter failure is caused 80% of the time by a faulty voltage regulator. However, repair in the field is tricky and the component should be returned to the distributor or the manufacturer. Some downconverters like those on the Drake line of receivers require that a small jumper cable be attached between two terminals on the downconverter to send power to the LNA. If this has been omitted, the LNA will not be powered.

If full power is registered, disconnect the pigtail from the LNA ouput and measure voltage on the cable. This will show a good or a shorted pigtail. If the reading is above 15 volts DC then the problem lies in the LNA which should be returned for repair or replacement.

Note that it is wise to have extra components on hand so a bad one can be temporarily replaced. Most customers will appreciate not loosing their satellite television during the time these faulty components are being repaired.

Also, note that similar techniques can be used to ensure that the proper voltages are reaching the polarizer as well as the actuator motor. The path can be traced from the controller or, if voltage is present at the peripheral equipment, it can be followed in reverse from out-doors to either the receiver or actuator control box. Note when checking voltages on the actuator motor two people are required, one to activate the motor via the control box and one to take the reading at the motor.

There is a simple method to use a meter to check both continuity and shorting of cables. If a coaxial cable is suspected of having a break, follow this procedure. Set the volt/ohm meter on the ohms x 10 scale. Now, use alligator clips to join the central conductor and ground together at one end. At the other end, attach the meter. If the meter reads zero ohms then there is no discontinuity; otherwise you have a broken cable. If the alligator clips are not used and a resistance reading is taken on the disconnected cable, a zero resistance shows there is a short between the central conductor and the ground shield.

When a connector is shorted, look first to see if there is any mechanical cause. Sometimes water is soaked into a cable at a leaky connector like wax is drawn up a wick on a candle. This "wicking" can pull water into a cable as far as 12 inches or more. If this is the case, the sign is usually a discoloration of the center conductor. If the cable is made from aluminum it can be severely corroded. Cut back until the discoloration disapperars and reattach a new connector.

Portable Signal Simulators

A portable signal simulator can be used to quickly diagnose system problems. Such a de-

vice transmits a signal which mimics those received from a satellite. We shall use the Newton Electronics GBS 1600 as an example (note that GBS stands for ground based satellite).

The GBS 1600 has three types of outputs, all relayed as color bar patterns: a C-band microwave signal; one at 70 MHz, the final IF for most receivers; and one tuned to VHF channels 3 or 4. These can be fed into a satellite system at various points to determine which components, from the LNA to the television set, are in need of repair or replacement.

The GBS 1600 is capable of providing both normal and inverted video. The audio subcarrier frequency is switchable between 6.2 and 6.8 MHz on both the C-band and 70 MHz signal. Note that since this diagnostic unit is battery powered there is no need for a bulky extension cord trailing behind during the troubleshooting. This battery lasts about two hours before needing recharging.

If the "souper feed," a small soup can with a built-in antenna, is aimed into the dish and the satellite receiving system is functioning

Figure 7-2. The GBS-1600 Portable Signal Simulator. *This piece of test equipment generates color bar patterns on channels 1, 12 and 24 which can be inserted at any point in a satellite receiving system. It is a very effective tool at quickly diagnosing the location of a problem. (Courtesy of Newton Electronics, Inc.).*

properly, clear color bars should be seen on the screen if the receiver is tuned to the correct channel. The video receiver must be set on either transponder 1, 12 or 24 since the GBS 1600 broadcasts only on these C-band frequencies. This check shows whether or not a satellite has not been targeted properly and can prove that the RF system is functioning.

If color bars are not seen, the LNA can be bypassed by connecting the 4 gigaHertz N-connector output from the signal simulator directly into the downconverter via a pigtail. The signal level from this output port is -20.0 dBm (one hundredth of a millivolt), more than enough power to drive long coaxial cable runs from the antenna to the receiver. If color bars are

now seen when the receiver is turned on, the LNA is defective. The 1600 can also be used to make certain that the downconverter is providing the necessary 15 volts DC to the LNA. A light on its front panel will be on if there is adequate voltage at the downconverter input.

Note that this particular instrument has only a 70 MHz IF output. So a block downconversion system which requires an intermediate frequency such as 950 to 1450 MHz cannot be tested with the 70 MHz output without the use of a substitute block downconverter which operates in the same frequency range. At the time of printing, no other low-cost simulators are available.

If color bars are still not seen, the downconverter can be bypassed by connecting the 70 MHz simulator signal into the coaxial cable going to the receiver. If color bars are seen the downconverter is faulty.

If the test pattern is still not detected on the TV, the simulator can be connected directly into the video receiver. This test is used to determine if the cable between the receiver and downconverter is faulty. If this is not the problem, then the channel 3 output of the 1600 can be connected directly into the television. This may show to the surprise of all, especially the customer, that the channel 3 input or the set itself is faulty. If the television is functioning properly then there is a problem with the satellite receiver.

If all these components are found to be working, then the problem may be something as simple as a tree screening the satellite signal, a non-functioning polarity selector or even a noisy, partially corroded connector.

It is clear that a portable signal simulator can be a valuable tool in testing for all possible failures that can befall a satellite TV system.

Another much simpler diagnostic tool is a portable florescent light, also a source of microwave energy. If it is waved in front of a functioning LNA some change in noise level should be seen on the television. If this is not the case, the LNA may not be receiving adequate power or may be defective. Similarly, the human hand is a source of 300 K noise. So placing it in front of a feedhorn should cause a rise in the signal meter on a healthy system with a sensitive meter. Of course, this action will blank out any picture which might have been present if a satellite was targeted.

Portable Receivers

Portable test signal simulators are valuable, but will not help in aligning an antenna onto the satellite arc. This job is best accomplished with a portable receiver or other sensitive tweaking instruments described in Chapter IV.

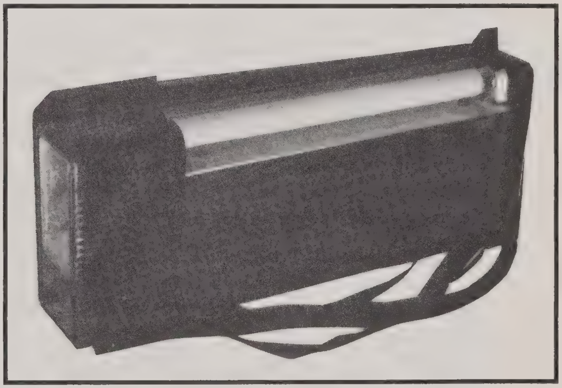


Figure 7-3. A Portable Florescent Light. *This portable light can be used as a simple tool to diagnose the condition of an LNA. In addition to generating light, it emits microwaves covering a broad frequency band. When waved in front of a properly functioning LNA, the noise level should change on the television set and the signal level should go to full scale.*

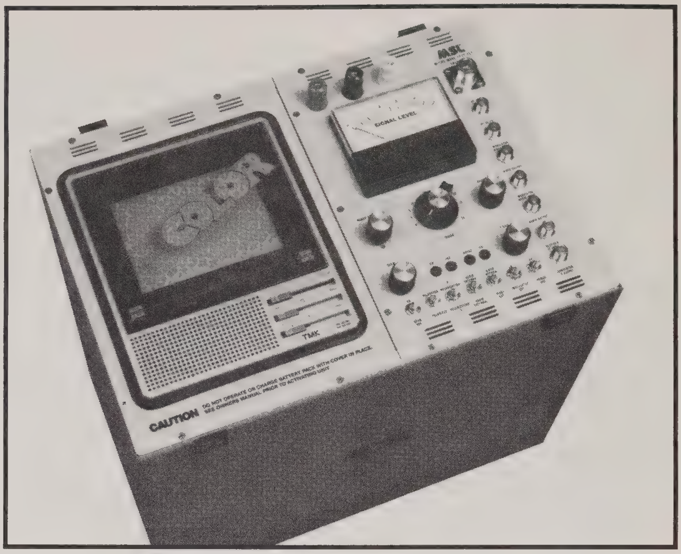


Figure 7-4. MSL Portable Test Receiver. *This test model has a 5 inch color monitor plus a complete set of fully operational earth station components except for a low noise amplifier. It can be either battery or line operated and has 18 volts DC available at the front panel for bench tests. (Courtesy of Micro Scientific Labs, Inc.).*

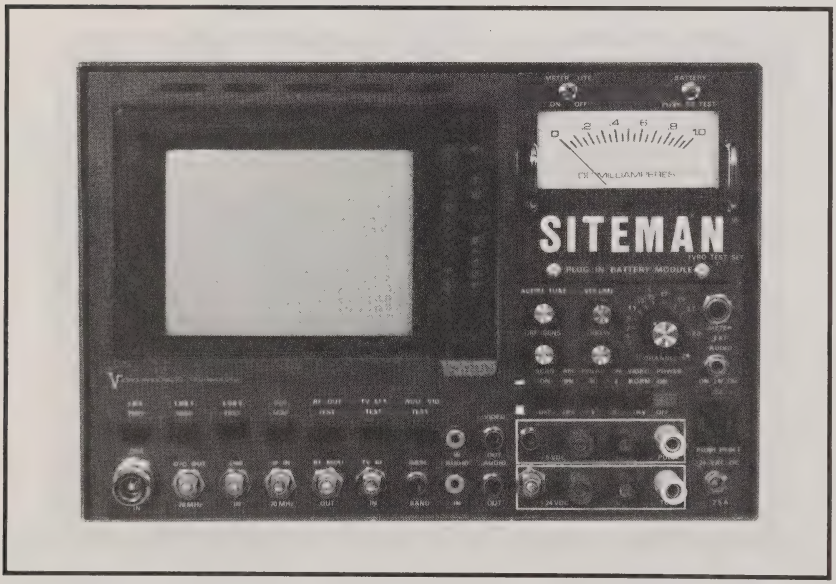


Figure 7-5. Siteman™ TVRO Test Set. *This portable test receiver has a 5 inch color monitor plus a complete set of fully operational earth station components except for a low noise amplifier. It has an audible tone in addition to a signal strength meter to facilitate dish position adjustments and can accept both C- and Ku-band inputs. (Courtesy of Video Products Technology).*

Many installers simply use the customer's receiver or an extra unit from the shop. Using a self-contained portable satellite receiver avoids the difficulty of hooking up 3 or 4 components as well as lugging a TV monitor or set to the site each time a test is conducted.

Mosts units today are battery operated and are equipped with either a color or black and white monitor all contained in a small portable box. All that is needed is an LNA. Portable receivers may be heavy, but using them reduces the risk of forgetting some necessary component back at the shop or of dropping a customer's prized set in the mud during testing.

A portable receiver can be used just like a signal simulator in reverse. The LNA output can first be connected to the portable receiver. If a good picture is seen on the small TV monitor, the problem lies in between the downconverter and the customer's set. Next, the output of the downconverter can be connected to the IF input of the portable test unit. Thus, by working from the dish towards the television, the faulty component can be ultimately identified.

There is a process called "half-split" troubleshooting. Instead of checking each component sequentially, the diagnosis can begin somewhere in the middle of the system. Thus might save time if the input components seeemed to be working fine but the nothing was happening at the output, the television set.

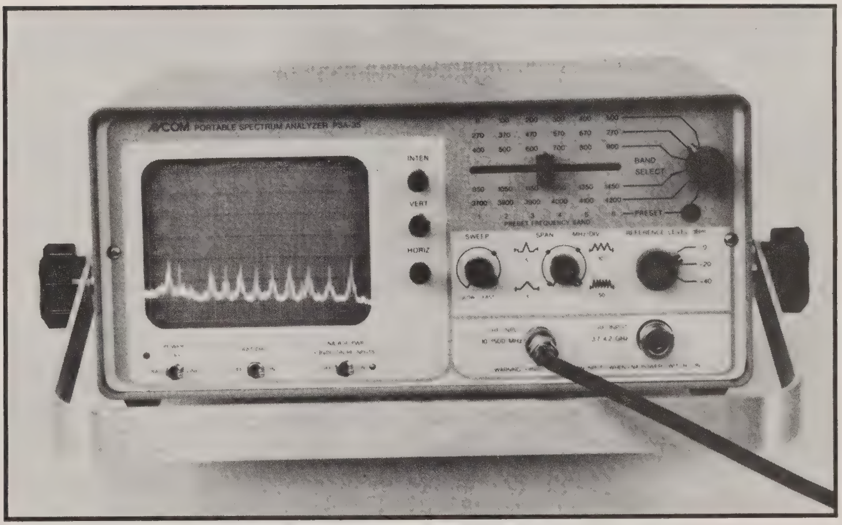


Figure 7-6. Avcom PSA-35 Spectrum Analyzer. *This portable spectrum analyser operates with an input below 3.7 GHz to above 4.2 GHz and with frequencies in six bands ranging from 10 to 1500 MHz. It has built-in DC power for driving low noise amplifiers. It is battery powered or can be connected to standard 110 VAC power line. (Courtesy of Avcom of Virginia, Inc.).*

Spectrum Analysers

Spectrum analysers are powerful diagnostic tools which show the frequency and power of microwaves coming from any chosen direction and having any given polarization. An LNA, or preferably an LNA and feedhorn assembly, scanned across the sky, is used as an input. A spectrum analyser can also be used to aim the satellite dish and peak the feed system. This is the most sensitive tweaking instrument available.

The screen of a spectrum analyser will display a graph of the power of the detected radiation versus its frequency. A range of scales for both power and frequency can be chosen so that fine details can be examined or so that the whole picture can be seen at once. These instruments are relatively expensive so a dealer must weigh the costs and benefits of using them versus arriving at the same results with less expensive methods.

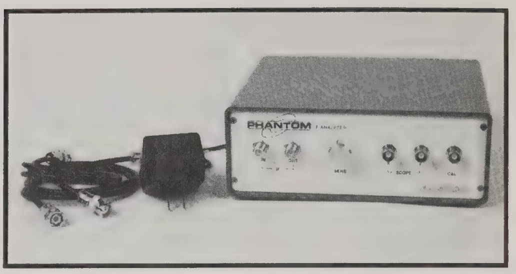


Figure 7-7. The SA-5090 IF Analyser. *This instrument when coupled with an oscilloscope can be used to visualize the signal centered on a final IF of either 70 MHz or 134 MHz. Filters can then be adjusted for maximum reduction of interference. (Courtesy of Phantom Engineering).*

E. UNDERSTANDING COMPONENT FAILURES

One approach to troubleshooting is to examine the operation of all components in order to understand how each may fail. This background knowledge aids in following the methods described earlier.

Satellite Receiver

The function and operation of the receiver should be clearly understood by a competent troubleshooter. It is crucial to be versed in the alignment procedures for each unit installed to avoid many potential problems. A dealer should also be familiar with all front panel controls such as use of skew controls, subcarrier selection, or scan selection.

A visual inspection of all feedback lights, fuses and connections and measurement of voltages will often reveal a simple problem. If this is not the case, more technical approaches can be used to determine any fault. One simple alternative is to swap an identical working unit and see if the trouble disappears.

Some more common problems encountered are listed below:

1. A high signal strength meter reading but no picture. If everything else seems to be work-

ing as expected including the TV set being on the right channel, this can be caused by a bad internal modulator. Note that most receivers use ASTEC modulators. Replacements are available in most Radio Shack stores but make sure that one which is "linear" is purchased. Non-linear brands are intended for use in computers. Only crystal controlled modulators should be used.

2. A zero signal strength indication with no picture. This may be caused by a shorted IF or voltage cable, lack of powering voltages or a problem somewhere else in the system like the dish not properly targeting the satellite.

3. The receiver shuts off when it is hot. A thermal overload is often caused by a voltage regulator overheating. A can of cold spray or a hair dryer may help isolate the defective component. The problem may be solved by simply clearing enough room to allow free air flow around the receiver vents. Occasionally a defective component may have to be repaired in the shop.

4. A herringbone pattern in the picture. This can be caused by a bad modulator, unwanted feedback from the 70 MHz line IF into the modulator or out-of-band TI. A strong, nearby FM station or transmitter may also cause the same problem if signals leak into the system through poorly shielded cables or components.

5. A lack of audio. This may be a problem in either the receiver or modulator. Check all connections and make sure the right audio subcarrier is being selected. If you listen with a pair of headphones at the receiver's audio output port and hear faint sound, the modulator is probably bad.

6. A buzz in the audio. This can be caused by a faulty modulator, incorrect audio tuning or a high video level in the modulator. Also associated with the high video level is saturated colors appearing on the screen.

7. Thick black bars across the TV screen. This is often a symptom of a faulty power supply caused by an irregular DC voltage. A 4700 microfarad, 25 volt capacitor applied across the DC rail may quickly solve this problem but the underlying cause should also be found and corrected (see below in the treatment of hum bars for some more details).

Aside from swapping out a voltage regulator or visually inspecting internal components, most repair work on a video receiver should be done in the shop. There is nothing worse than scattering parts from a reciever all over a customer's home and then not having the components necessary to fix it when you discover the problem. By this time some of the screws have been lost in the three inch shag carpet and the customer is starting to look worried.

Stereo Processor

Troubleshooting either a stand-alone stereo processor or one built into a receiver is usually limited to educating the user about its proper operation. Many may believe that since the system has a stereo processor, all audio should now be received in stereo. Most stereo processors have too many unfamiliar buttons for the novice user. This can easily lead to incorrect operation. Note that a satellite TV guide lists the correct audio formats for use with stereo processors.

A first step is to tune to a known channel that employs a stereo format that the processor can demodulate. Most can manage the MTV format. Select matrix stereo position on the processor controls and tune both subcarrier channels to the correct position. If stereo is not heard, the problem may lie with the customer's stereo system. This can be ascertained by tuning their stereo receiver to a known source such as FM radio, a record or a tape.

In those cases where the customer's stereo is functioning properly but no stereo can be obtained, first make sure the leads are connected securely. A voltage reading can be taken

to determine if a signal is actually reaching both ends of the audio cables. Make absolutely sure that the stereo processor is connected to the baseband output of the receiver, not the audio output which is used to drive an external modulator. If these tests are negative, the best course of action is to swap it out for a working unit and take it back to the shop for necessary repairs.

Cable and Connectors

Coaxial cable and connectors can easily be overlooked as potential sources of trouble. But incorrect installation procedures and selection of cables can often cause substantial deterioration in overall performance.

A poorly grounded cable or a connector which leaks moisture can introduce unwanted noise or can severely attenuate signals. A cable which is bent too sharply can result in signal losses because its impedance will change at the bend and cause signals to be partially reflected. Improperly installed direct burial cable and leaky connectors can corrode in surprisingly rapid times.

When installing cables and connectors it is imperative to securely crimp the casing onto the shield wires. All locations where water may enter must be sealed and protected as well as possible. Coaxial sealant must be used to prevent water ingress at all outside, exposed locations.

Troubleshooting cables and connectors can be as simple as a visual inspection. If necessary, a continuity test will make sure that signals can pass without serious or complete attentuation. Note that if wire or cable having too fine a gauge is used for long runs, insufficient voltages reaching the downconverter, LNA or probe rotator may cause faulty operation as outlined below.

If water does leak into coaxial cable this can cause a receiver to jump channels. This occurs because the tuning voltage being sent to the downconverter is shifted and has changed the oscillator frequency. If wicking occurs, cut back the cable 8 to 12 inches and install a new connector.

Downconverter

A faulty downconverter can be the source of numerous problems, some of which can show similar symptoms to those caused by a failing LNA.

Single and dual downconverters can suffer from drifting between channels due to ambient temperature changes. Oscillators can have slightly different output frequencies depending upon whether they are operating in hot or cold environments. A partial cure for this problem is to leave the power on all the time. This practice allows heat to build up in the downconverter and minimizes reactions to outside temperature changes. Automatic frequency controls are designed to compensate as well as possible for such variations. If the AFC control has been disabled to combat TI, this drifting could be worse. Note that block downconverters are nearly immune to drifting because the whole 500 MHz band is lowered in one step and channel selection is accomplished in-doors.

If a downconverter is poorly shielded, it may be susceptible to interference coming from communicators using the same operating frequency range. A poorly shielded downconverter may also emit unwanted signals. When mounted behind the LNA at the dish focus, a downconverter can send interfering radiation back into the dish and subsequently into the feedhorn. We recommend that single downconverters which can generate interfering frequencies in the C-band always be mounted behind a dish in a weatherproof box. Note that a downconverter mounted at the dish focus is also susceptible to focused solar energy and the resulting temperature extremes can worsen drifting between channels.

Downconverters not housed in weatherproofed boxes may gradually become leaky as water freezes and thaws at joints or water enters as condensation. Water ingress can destroy sensitive circuits by oxidizing copper tracks on circuit boards. The early signs of water damage can be an overly noisy signal and the resulting sparklies.

When two single conversion downconverters are located on the same dish, as in a multiple channel hookup or on two nearby systems, they can interfere with each other. This can occur because the oscillator frequency generated in the downconversion step falls 70 MHz higher or lower than the desired signal. These in-band signals can interfere with lower or higher channels sharing the same frequencies. A cure for this problem is to install a ferrite isolator on the N-connector, 4 GHz side of the downconverter. This device allows the RF signal from the LNA into the downconverter but stops the undersired frequency from leaking out up the cable into the dish and possibly into the second downconverter.

Single downconverters connected directly to an LNA via a double male N-connector can possibly radiate interfering signals back into the dish and be redetected as additional noise. Also, sometimes the signal coming out from the LNA may be strong enough to overdrive the downconverter and cause intermodulation distortion and extra noise. If the downconverter were mounted behind the dish and fed by a 10 foot RG-214 cable, losses in this coax would probably prevent this outcome.

It is interesting to realize that if the downconverter output does leak back into the antenna it could be reflected towards and interfere with a neighbors off-air TV reception. This is because channel 4, located at 66 to 72 MHz, shares the same band as the 70 MHz downconversion intermediate frequency.

A faulty downconverter can show up as a blown fuse in the receiver. If fuses keep on blowing even after the LNA is disconnected from the downconverter, the problem can often be traced to the downconverter.

Low Noise Amplifier

A faulty LNA or LNB can cause problems ranging from excessively sparklie pictures to complete white out. Some common symptoms and their causes are:

1. Lack of voltage to the LNA. This probably results from a blown fuse in the receiver or a bad downconverter. Note that a simple method to check LNA voltage is to disconnect the pigtail line and measure voltage between ground and the central conductor. 15 to 24 volts DC should be read at that point. Be careful not to short the leads together.

2. An opened circuit at the LNA output. One or more of the LNA stages may be blown. There will be no signal strength reading at the receiver and the TV picture will be blank white.

3. Excessively sparklie pictures. One or more LNA stages may be faulty resulting in noise temperatures in excess of rated values. Switching in a good LNA is a quick troubleshooting procedure if this is suspected.

4. Presence of hum bars. Hum bars are horizontal lines of varying thickness which can ruin a picture. They may be of any width and can move up or down across the screen. Low voltage at the LNA is one cause of hum bars. Most LNAs require a minimum of at least 15 volts DC and 150 milliamps of current to function correctly.

5. A blank TV screen. This may be caused by a faulty LNA. To determine if the LNA is powered and operating, connect and disconnect the LNA cable while observing the television screen. If the noise level on the picture does not change, the LNA is probably at fault or is not receiving power. Another check for a faulty LNA is to wave a florescent light in front

of the feedhorn. If the noise level does not change the LNA is probably faulty or not receiving power.

6. Picture deteriorates in hot or cold weather. This problem can be isolated by using a can of freeze spray or a hair drier to change the temperature of the LNA.

LNAs are finely tuned pieces of equipment. A faulty unit should be returned to the manufacturer for repair.

Feedhorn

Feedhorns are precisely machined waveguides designed to efficiently capture C-band microwaves. Any obstructions in the throat can detune the waveguide and seriously impair performance. Some commonly encountered symptoms of problems are:

1. Excessively sparklie pictures. This may be caused by wasps, water, ice or other obstacles lodged in the waveguide throat. If water is not removed it could freeze and crack the housing. When using the 90° waveguide elbow with the polarizer, a cure is to drill a very small hole (less than 1/16th of an inch) in the lower corner of the right angle guide to allow water drainage.

Such performance impairments may also be caused by a bent or mechanically distorted probe. But remember, never readjust the probe position even if it appears to be bent. These are finely tuned devices.

2. Signals of only one polarity are received. This probably indicates a bad servo or DC probe motor. Remember that burnout can be caused by improperly installing servo motors without allowing for full 180° freedom of motion at the correct position. This can also be caused by using a wire gauge that is too small for the cable length used or by not using shielded wires.

3. Oscillation or servo hunting of the probe. A random oscillation in a servo motor polarity selection device can appear in the form of black bars or white lines on a TV screen. In severe forms it may show up as a jumping between two adjacent channels of opposite polarity as the probe hunts intermittently around its axis. This can be easily differentiated from channel drifting because the same two channels are always seen. An easy method to prove the problem is caused by servo hunting is to disconnect the polarity selection connections. If the problem disappears, it cause is evident.

Most often this occurs with system cable runs exceeding 80 feet when using an undersized wire. The solution to this problem is to install a 1000 microfarad, 10-volt DC electrolytic capacitor between the red +5 volt wire and ground which is black on the motor. The capacitor should be connected so the plus on the capacitor is connected to the +5 volt and the minus side to ground. To prevent oscillation, the following minimum wire sizes as shown in Table 4-7 should be observed.

Antenna Actuators

A well designed and manufactured antenna actuator is usually quite reliable when installed correctly. However, there can be large quality differences between different brands and proper equipment selection will save troubleshooting and repair time.

The actuator consists of a mechanical assembly and its electronic control circuitry. The mechanical component serves to hold the antennna in place and to provide movement across the polar arc while the controller keeps track of the dish position. Some common symptoms and underlying causes for mechanical failures are as follows:

1. Inaccurate pointing of the antenna. If there is too much play in the movement of either the

inner or outer tubes (or gears or a chain drive in the case of a horizon-to-horizon assembly) then some wearing or loosening of parts has occurred. If the dish has more than one inch of play in either direction at its rim, the mount needs attention. The bolts supporting the pivot points or jack attachment should have double nuts, lock washers and lock-tight and be tightly set.

2. Wear or scoring on the jack tube. This may result when the internal O-rings are damaged by lateral stress being applied when the arm is not installed using ball joints. Waterproofing should be correctly done so that water does not leak into the casing and motor assembly.

3. The jack tube is binding or even bending as satellites are tracked. This may occur if both ends of the jack arm have not been properly aligned and mounted on self-adjusting ball joints. A single ball joint on one end is not enough. The jack should be able to track through its entire range of possible motion without binding on either the dish or mount structure. Therefore, if the electrical east/west limits fail, damage to the arm will not occur. The motor may also have failed possibly due to water damage. It makes senses to have a spare motor or brushes for placement around the armature.

4. Water entering the motor housing or the tube. Water can collect inside the arm or housing if they have not been properly sealed by gaskets or a rubber boot. Even so, condensation can cause water to collect, freeze, seize the motion and even damage the housing. Drain holes must be in their correct position to prevent this chain of events from occuring. Note that a neoprene rubber accordian sleeve with a hole at either end to allow condensed water to escape is an excellent method to prevent water ingress.

5. A grid of dots appears on the TV screen. Some control boxes cause interference on channels 2 or 3. The internal 3 to 6 MHz clock crystal that runs the microprocessor makes a grid of evenly spaced dots appear of the screen. This effect sometimes occurs when the actuator is set ontop of the TV set and beats directly into the tuner. Or if 300-ohm flat, twin lead cable is used to feed off-air broadcasts into the TV, it may also pick up the signal from the clock crystal. These dots can also appear on satellite TV channels but can be easily eliminated by using a 10 dB line amplifier on the receiver output to overpower the interference.

The most common types of feedback circuits used for actuator control are Hall effect sensors, Reed relay switches, 10-turn potentiometers and photo optical readouts. Most are coupled to a central microprocessor. Each has its own set of potential problems and solutions.

Feedback potentiometers receive a constant voltage and divide it into a smaller portion depending upon the position of the dish. This returned voltage is calibrated and fed onto a readout on the face of the controller.

If the pot breaks or becomes disengaged from the drive pin in the motor, a dish can be driven too far and the jack tube can be bent. A preset electronic and mechanical limit is an important feature for such control systems.

A method to troubleshoot this type of drive is to use a spare 5 K-ohm potentiometer. It can be temporarily installed in place of the permanent one by simply disconnecting it and reconnecting the two or three wires. If readout numbers change on the control box when the temporary pot is adjusted then the problem is in the motor; if not, the problem is in the control box.

To troubleshoot a unit with a Reed switch or Hall effect transistor in the motor, attach an alligator clip between the pulse and ground connector at the control box after disconnecting the pulse input line. As the drive is moved in either direction, make and break the connection on the pulse and ground wires to simulate drive pulses. If the controller works properly and does not display an error, then the problem is in the sensor or the cable connection between

the motor and control. Troubleshoot for cable continuity.

One method of troubleshooting a Hall effect sensor at either the controller or motor is by reading voltage between the pulse and ground points. A drop of about 0.75 volts should be measured when the east or west button is pressed. If not, then the Hall effect transistor is bad. If the sensor itself is not faulty, check that the magnets on the motor have not moved or fallen out of place. A spare Hall sensor and Reed switch are useful additions to a troubleshooters spare parts kit.

It is important to always use shielded sensor cable on Hall effect or Reed sensors. These devices will give spurious readings if they pick up outside noise. Even the inductive action of a starting or stopping motor can be detected as a "spike" in the sensor. This added to the control count would cause a cumulative error in measuring dish position. After the problem has been corrected, the actuator control must be resynchronized because each satellite will probably be missed by the same amount.

Make sure that the magnets surrounding these two types of sensors have not been dislodged. If they have, remember that magnets have a positive and negative end and should be reinserted all facing in the correct direction.

The ground lug on the controller power cord must never be cut to try to fit the three prong plug into a two prong outlet. The microprocessor relies on an accurate ground to accurately set its counting circuitry. Always use some type of surge protection on the power line into an actuator to protect the microprocessor. Note that if a problem does develop in the internal circuitry of an actuator, the best bet is to return it to the manufacturer for repair.

Dish and Mount

Troubleshooting a dish and mount is a relatively easy matter of conducting an educated visual inspection. Dishes should be checked for warpage and surface imperfections. Mounts must be examined for stability, alignment and secure connections. The feedhorn/LNA support structure can be checked for centering and stability. Methods to perform all these checks have been outlined earlier.

TV Set

A television is a complex piece of electronic equipment. However, troubleshooting a TV is easy when off-air channels of adequate signal strength are present. If the set works well with conventional reception then about the only problems which can be encountered are channels 3 or 4 not being tuned in properly.

Note that there are major differences in the quality between different brands of televisions sets. It would be wise for a well-equipped troubleshooter/installer to carry a small, portable, excellent quality television or monitor to demonstrate if there ever is a question about the performance of a satellite system. After all, most judgements are made on the basis of picture quality. Also, if a monitor is used, a faulty modulator internal to a receiver can easily be diagnosed since it would be bypassed.

F. A LOOK AT SOME MORE GENERAL PROBLEMS

Occasionally problems arise which cannot be traced to a single faulty component but are related to how all the components and wiring fit together. Troubleshooting such animals can be somewhat more difficult but also more rewarding than simply replacing a bad LNA or finding a shorted cable.

Hum bars are a good example of this type of system difficulty. Hum bars appear on a television as messy horizontal regions of varying width which may be stationary or which can move up or down on the screen. They can be caused by either a ground loop or inadequate voltages. A ground loop results from having two grounding points at slightly different voltages in a system. For example, if both the dish and receiver are grounded in different locations such a problem may arise. The difference in ground potential shows up on the coaxial cable and causes the picture to lose some of the necessary synchronizing ability.

There are two types of ground loops. Those that appear long after the installation is completed are usually caused by bad conections. Those that appear during installation can, on occasion, be tricky to cure. However, one of two methods usually works. The first cure is to eliminate any bad connections in the satellite system or, perhaps, in the home's ground connection wiring. A second method is to tie all of the interconnected satellite equipment together with a common ground. Thus, running a heavy gauge wire between the receiver and downconverter casing can often eliminate a ground loop. Or the antenna can be tied directly in the electrical service ground at the point that it enters the home with a heavy gauge (e.g. #6) cable.

Inadequate system voltages can have the same effect by not providing enough power to generate the necessary signal to properly drive the receiver. This could happen if undersized wire is used on a long run to the LNA or downconverter so that the cumulative cable resistance causes unacceptably large voltage drops. The same symptom may be seen if the feedhorn probe servo hunts. This is also caused by inadequate voltages in undersized cables spanning long distances.

Such multi-cause symptoms are the reason troubleshooting is usually more effective by following the interview/visual inspection/technical sequence that by trying to treat symptoms immediately.

Another example of a problem resulting from the interaction of system components can occur as follows. Over time a customer complains that picture quality is slowly worsening. Upon closer examination the competent troubleshooter discovers that the system, which was installed by another less competent dealer, has a slightly undersized 6 foot dish. Everything was fine on clear days. When it rained the picture was still barely acceptable. Then the low quality dish began to warp slightly, small amounts of moisture began to accumulate in the feedhorn and one F-connector developed a slight case of corrosion. None of these problems would have been enough to cause a serious concern; all together they created unacceptable performance degradation.

G. COMBATTING TERRESTRIAL INTERFERENCE

Terrestrial interference can be an annoying problem whose symptoms can often mimic those caused by components failures. However, a trained troubleshooter should be able to recognize and diagnose TI without too much difficulty.

A site check should be used to find a location where TI can be avoided. Or, if necessary, man-made screens or appropriately inserted filters should have been used to eliminate TI. But what if someone else had done the installation, had not recognized light to moderate levels of TI and is now out of business. Or what if a new earth-based repeater station begins to adversely affect a satellite TV system which previously had no problems.

A dealer who understands and can treat cases of TI, especially in metropolitan areas having heavy data and telephone traffic, is often in the position of a doctor who has a cure for cancer. Business will be good.

Symptoms of TI

TI can be classified into two general categories: the ingress interference band; and the antenna interference band. The latter is divided into out-of-band and in-band interference. The basic principles underlying TI were discussed in some detail in Chapter III and IV. The symptoms of each of these types of TI are distinguishable and can be used as a basis to select the appropriate cure.

Ingress TI

The primary symptom of ingress interference is an identical problem on all satellite channels. Such interference usually occurs when unwanted carriers in the 5 MHz to 1 GHz range enter the system because of poor equipment shielding, faulty connectors or improper grounding or through poorly filtered power lines.

Ingress TI could show up when VHF TV channels 2 through 6, which occupy the 54 to 88 MHz band, leak into a poorly shielded receiver. Co-channel interference caused by off-air channels being detected on a poorly shielded modulator to TV cable can also have similar symptoms, a faint second picture in the background or "venetian blinds" across the screen. Never use a shielded flat, two-wire cable called a twin lead from the modulator to TV. A well grounded coax will eliminate this problem.

Also, the amateur radio band frequencies, 1.79, 3.58 and 7.15 MHz, occupy the same frequency region where the baseband video and the audio subcarriers reside. Detection of the two lower frequencies could cause herringbone patterns on the screen; interference from the latter could cause an audio buzz. All of these irregularities would be seen on all satellite channels.

Out-of-Band TI

Out-of-band TI is not as rare an occurance as ingress interference but is still quite unusual because most LNAs have built-in bandpass filters. The closer an interfering carrier is to the edge of the C-band and the stronger its level, the more pronounced will be the effects.

Symptoms of out-of-band TI are disturbances at either end of the satellite channel range with effects decreasing on channels further away from the band edge. Generally, only channels

having the same polarization as the TI will be affected. So a strong indicator of this type of TI is also picture deterioration on every other channel near either edge. Horizontal lines across a picture are often a result of out-of-band TI. This effect can be caused by detection of broadcasts from a local multipoint distribution system (MDS) operating at about a 2 GHz frequency. MDS systems use one large microwave transmitter in a given area which is received by many very small, "tin-can" antennas with the necessary electronics.

Out-of-band interference can usually be cured by placing a bandpass filter between the LNA and downconverter. In rare cases when the signal level is so high as to overdrive the LNA, the filter must be inserted between the feedhorn and LNA.

In-Band TI

In-band TI also has characteristic signs. Since land-based repeater stations usually relay 6 frequencies each spaced 80 MHz apart, picture distortion is often seen on every other channel. As power levels of the interfering carriers increase, channels adjacent to these can be affected. If fewer carriers are in use, as little as one channel could be affected. The degree of picture deterioration also depends upon the bandwidth of the interfering signal. For telephone relays this is determined by how many conversations are being relayed at a time. As more people come on line the bandwidth increases until the transponder is completely wiped out. This occurs most often in the late afternoon when telepone traffic is at a peak. The varying signal strength meter often seen when TI is present reflects the changing bandwidth as thousands of people make and break telephone links.

The interference pattern across channels caused by two sets of carriers is somewhat more complex (see Chapter III for more details). Generally if two transmitting antennas are used, they have opposite polarity signals or widely spaced frequencies. Twelve horizontal and twelve vertical channels can be affected in these cases.

As the TI level increases so does picture deterioration. The following table illustrate what effect interference can have on a satellite broadcast. TI levels are expressed relative to the satellite signal received at the downconverter. To actually measure these relative levels a spectrum analyser must be used.

TABLE 7-2. PICTURE DETERIORATION AND TI LEVEL
(Courtesy of the Microwave Filter Company)

TI Level	Description of Degradation
-25 to -15 db	None to very slight degradation; picture becomes busy but has no well-defined picture defects.
-15 to -10 db	Busy picture to light sparklies
-10 to -5 db	Light sparklies to an unwatchable flurry.
-5 to 0 db	Flurries fill in more and more of the picture, and black sparklies and/or black broken horizontal lines appear.
0 to 5 db	Dark sparklies and lines degenerate into heavy horizontal bars; picture begins to jump due to loss of "synch;" finally, picture begins to disappear under heavy snow.
5 to 10 db	All traces of the picture disappear and the screen becomes blank except for a uniform, fine-grained texture.

Like out-of-band interference, in-band TI may disappear when the antenna is aimed at another satellite. Microwave interference, like satellite broadcasts, can be very directional.

Eliminating TI

By the time a troubleshooting call is necessary, the option of relocating an antenna being troubled by TI is a costly alternative. Usually finding a technical fix without resorting to more expensive artifical screening method is not too difficult. The details of these methods have been detailed in Chapters III and IV but a brief review is presented here.

Ingress interference is usually cured by "tightening up" the system which involves properly shielding and grounding all leads and ground connections. Out-of-band TI can most often be eliminated by proper placement of either microwave or RF filters. In-band interference usually calls for RF notch filters or sometimes microwave traps. The most difficult situations arise when the TI level is high relative to the satellite signal or when the carrier has a wide bandwith ranging from 5 to 30 MHz. Then either more expensive phase cancellation methods or screening methods must be used.

Frequency Coordination as Future Insurance

Until receive-only earth stations were deregulated in 1979, a license had to be obtained prior to installation. Today, the FCC still regulates uplinks. These require careful planning and a process called a frequency coordination.

The frequency coordination begins with a study of other nearby communicators sharing the same frequency band who might interfere with or be affected by the planned installation. A detailed map, usually created by computer from an extensive data base, shows where the potential sources of interference may lie. If all seem to be right, the license is granted. Any future sites which may affect this new one must likewise register with the FCC. In this fashion, all are protected from each other.

Few receive-only stations bother following the frequency coordination or licensing route. Some of the larger SMATV (satellite master antenna TV) systems serving hotels or apartment complexes often take this safer route. Home satellite dealers should also be aware of these services. For a price, a map of potential interfering communicators can be purchased.

H. TOOLS OF THE TRADE

If a site visit is necessary have the proper tools on hand. If you have driven 50 miles into the boonies and find that you are missing a 50 cent voltage regulator, this component just went up in price by $100.

All the light tools of the trade should be taken on a service call. This usually excludes conrete mixers and other large items. In addition, you should have a complete, operating spare system, possibly including a small test dish. This includes:

- Notch and bandpass TI filters
- Feedhorn with polarity selection
- Extra servo or DC motor for polarotor
- Modulator
- Inexpensive receiver and downconverter
- Ample supply of applicable fuses
- Appropriate voltage regulators
- Extra Reed switches or Hall sensors
- Spare brushes, motor or a complete actuator
- 5 K-ohm potentiometer
- Florescent light
- 1000 microfarad electrolytic capacitor
- Scotch locks
- Electrical tape, solder
- Splitters
- Assorted connectors
- 10 dB line amplifier

When assembling filters to be taken on a troubleshooting call, know the IF of the particular receiver at the site. IFs can be 70, 130, 134, 400 or 612 MHz.

A SYMPTOM/CAUSE MAP

The following table has been developed to aid a troubleshooter in making a rapid diagnosis of any potential system problem. This tool should be used as a complement and not a replacement to the detailed explanations which have already been presented earlier in this chapter.

TABLE 7-3. A SYMPTOM/CAUSE MAP

Components and Symptoms / Problems	Symmetrical Dots on Screen	Interference on Channels 2, 3, and 4	Every Other Channel Good	Motor Boat Sound in Audio	Buzz in Audio and Bright Colors on Video	One Polarity Only Received	Picture Comes and Goes	No Picture but High Signal Strength Reading	Actuator Jack Stuck	Good Video but No Audio	Good Audio but No Video	Receiver Blows Fuses	Lines in Picture	Horizontal Hum Bars and Line Rolling	Receiving Only Some Satellites	Satellites in Arc Center Snowy	Poor Video with Sparklies	Channel Drifting	Jack Moves but Controller Not Counting	Herringbone in Video	Flutter in Video	All Satellites Snowy	Video Good Only During Daytime	Video Bad at Night	Video Bad on Hot Day
Dish																	X								
Mount															X	X									
Feed Support																	X								
Jack, Actuator or Motor Sensor							X		X										X						
Low Noise Amplifier												X		X			X						X	X	X
Downconverter												X		X				X					X	X	
Feedhorn						X							X												
RG-214 Pigtail												X											X	X	
RG-6 or RG-59 Coax												X		X											
Cable Problems and Corrosion																	X					X			
Satellite Receiver										X	X			X				X			X				
Modulator					X			X		X	X									X					
Polarization Controller						X																			
Actuator Controller	X								X					X											
Signal Distribution		X											X	X											
Terrestrial Interference			X	X			X	X																	
Customer TV Set								X																	
Grounding														X											
Water In Actuator									X																
Water In Cable																		X				X			
Water In Feedhorn																	X								
Incorrect Voltages														X											
Dish Support																						X			
Polar Arc															X										

VIII. PROFESSIONALISM

The satellite TV industry is young and rapidly growing with opportunities for healthy profits. As a result, the business has matured from one populated only by technical enthusiasts to a stage where everybody wants to become a dealer. But the next phase is now upon us because mass merchandisers are rapidly entering this field which has revenues of over a billion dollars every year. The key to survival for both the small, independent dealer are well as the large retail outlet is professionalism.

A professional dealer knows his or her trade, is well equipped and understands customer relations. All three ingredients are necessary in order to project an image of someone who can properly install and service a satellite television system. After all, a consumer must have confidence to spend thousands of dollars for a system and then to refer his friends, family and neighbors to this dealer.

Telephone installers/servicepeople can be excellent models for satellite TV dealers. These people are professionally trained. When they arrive at a home first they introduce themselves, mention the name of their company to the customer and state the nature of their business. They are usually dressed in a familiar uniform and arrive with a work order. Their well-maintained, well-stocked vechicles are parked so as not to block the flow of traffic or the customer's driveway. A telephone repairman will not be seen borrowing a ladder or a wire cutters from a customer or a neighbor. They arrive on the scene with all the necessary tools. But before they lug all their tools to the door, they always introduce themselves and their companies. They must be sure that the customer is ready to receive someone into their home. The initial impression is of the polite introduction.

A professional satellite dealer must respect a customer's property as if it were his or her own. This is crucial. For example, when drilling a hole for a cable through an interior wall have a piece of plastic underneath to catch the debris. Always clean up all leftover messes, even the small pieces of wire resulting from attaching connectors or various sorts. Since the work is performed both in-doors and outside, be careful not to track mud into a customer's home or step on a prized flower bed. And be careful not to soil furniture or other prized possessions. Image how irate a customer could be to have a light colored couch stained with oil or mud. Laying tools ontop of expensive furniture or dropping a hot soldering iron onto an oriental carpet could evoke the same response. Always think about the customer's needs and tastes. After all the customer is the one who gives referrals and these are essential for a successful business.

When leaving a job it is very important to remove all waste materials. A partially filled bag of cement left on the site will not be a welcomed calling card. However, the customer

should be given all the paperwork and warrantees that come with each component as well as the box and its packing material in case the particular unit has to be returned to a distributor or manufacturer. Let the customer know that the boxes, especially those for the electronic components, should be kept for this possible outcome.

In general, it is best to repair faulty equipment back at the shop except if the job will be simple and quick. But do the repair work in an area which is well lit and which will not interfere with the customer. In those cases where the customer is a long drive away, be prepared with a portable table to do the necessary repair work.

A well-organized dealer/installer will thrive. Even the largest retail outlets need professionals to train and manage their growing staff of installers and troubleshooter. If these simple rules are respected and followed, customer relations can be excellent:

- Be punctual. Arrive at appointed times.
- Respect the customer's property and wishes. After all they are paying dearly earned money for equipment and installation expertise.
- Be polite and honest.
- Be knowledgeable about installation of the satellite TV which has been sold.
- Give a clear demonstration and explanation about the system before leaving the job site.
- Always clean up completely.
- Have the customer sign the work order indicating that they are satisfied that the job has been completed satisfactorily.
- Be prompt and courteous in responding to sevice calls.

The Professional Trade Association

SPACE, the Satellite Television Industry Association, consisting of dealers, distributors and manufacturers, was formed to promote the industry. This organization, which supports the concept of well-trained, professional dealers, has a certification program consisting of 10 practical courses covering technical, legal and business aspects of satellite television. In addition, a SPACE dealer member receives up-to-date information on a regular basis. This can be vital in keeping abreast of developments in order to better serve customers and increase profits.

The industry association can be contacted at:

SPACE
300 North Washington Street
Alexandria, VA 22314
(703) 549-6990

APPENDIX A
THE DECIBEL NOTATION

Decibels (abbreviated as dB) are used to express the relative values of two signals. The logarithmic scale is used to compress large differences in numbers to a more manageable range. Decibels are defined by the following equation:

$$\text{Decibel difference} = 10 \text{ logarithm (signal A/signal B)}$$

For example, if signal A is 1000 watts and signal B is 10 watts, then signal A is 20 dB stronger than signal B because:

$$\begin{aligned}\text{Decibel difference in power} &= 10 \log (1000/10) \\ &= 10 \times 2 \\ &= 20 \text{ dB}\end{aligned}$$

Therefore, if an amplifier received a signal of 10 watts and increased its strength by a factor of 100 to 1000 watts, it would have a gain of 20 dB. Similarly, if a 10 watt signal was increased by a factor of 1,000,000 to 10 million watts, the gain would be 60 dB.

Decibels are also expressed relative to a reference value such as watts or milliwatts. The abbreviations dBw and dBm mean the relative increase in power relative to one watt and to one milliwatt, respectively. For example, 20 dBm means a power of 100 milliwatts while 60 dBw means a power of 1 million watts.

APPENDIX B
SATELLITE FOOTPRINTS

These satellite footprints were provided to us by Chris Schultheiss, the editor and publisher of STV Magazine. We are grateful.

They have been assembled from thousands of measurement taken around the country on the STV road trip in the summer of 1984. The data was analysed by Mike Gustafson, their technical editor, and presented in the simplest readable form, suggested antenna size. The following assumptions were used:

8.0 dB Receiver Threshold
2.0 dB Margin Above Threshold
25 MHz Wide IF Bandwidth
85 K LNA
Antenna Gain at 3950 MHz
Antenna Efficiency of 55%

It is not difficult to use the link equations in reverse, so to speak, to calculate the satellite EIRP for each of these dish size lines. For example, the EIRP measurement which led to a choice of a 9 foot antenna can be found as follows:

$$C/N = EIRP + G - 10 \log T - 10 \log B + 31.80$$

therefore

$$EIRP = C/N - G + 10 \log T + 10 \log B - 31.80$$

All that we need to know is the assumed C/N which is 8.0 dB plus a 2.0 dB margin above threshold used by STV Magazine, the antenna and LNA noise temperature, antenna gain which can be found from tables or calculated, and the bandwidth expressed in megaHertz. We have assumed that the free space path loss is 196.3 decibels and another 0.5 dB is lost because of other factors such as pointing inaccuracies. Taking the antenna noise temperature from Figure 2-7 at a 35 degree elevation angle and calculating gain for a 9 foot, 55% efficient antenna from the formula in Appendix D, we find:

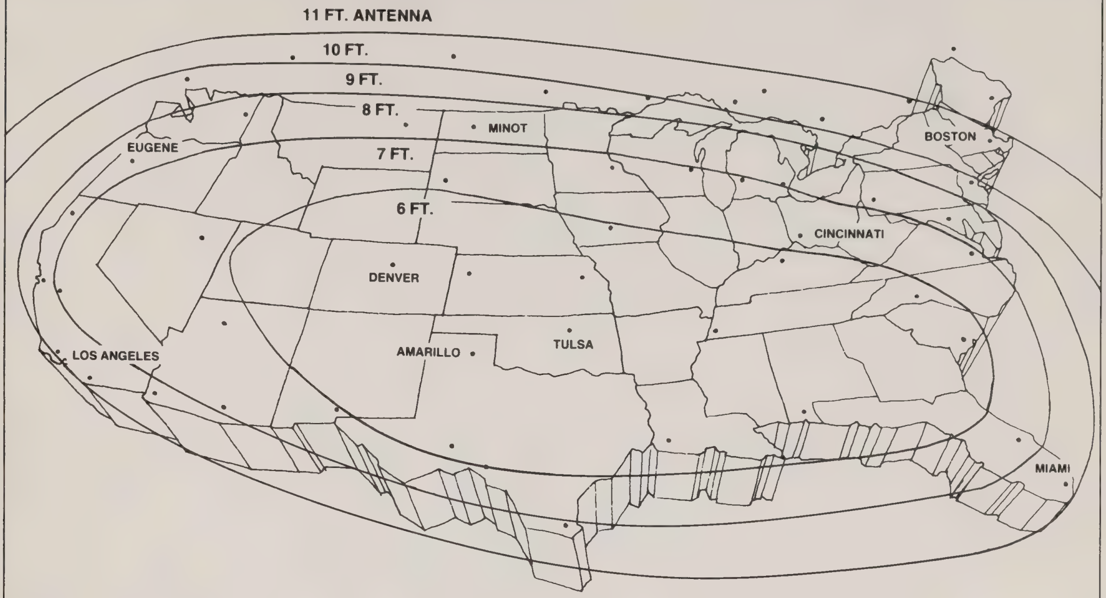
$$EIRP = 10.0 - 38.68 + 10\log(41+85) + 10\log 25{,}000{,}000 - 31.80$$

$$= 34.50 \text{ dBw}$$

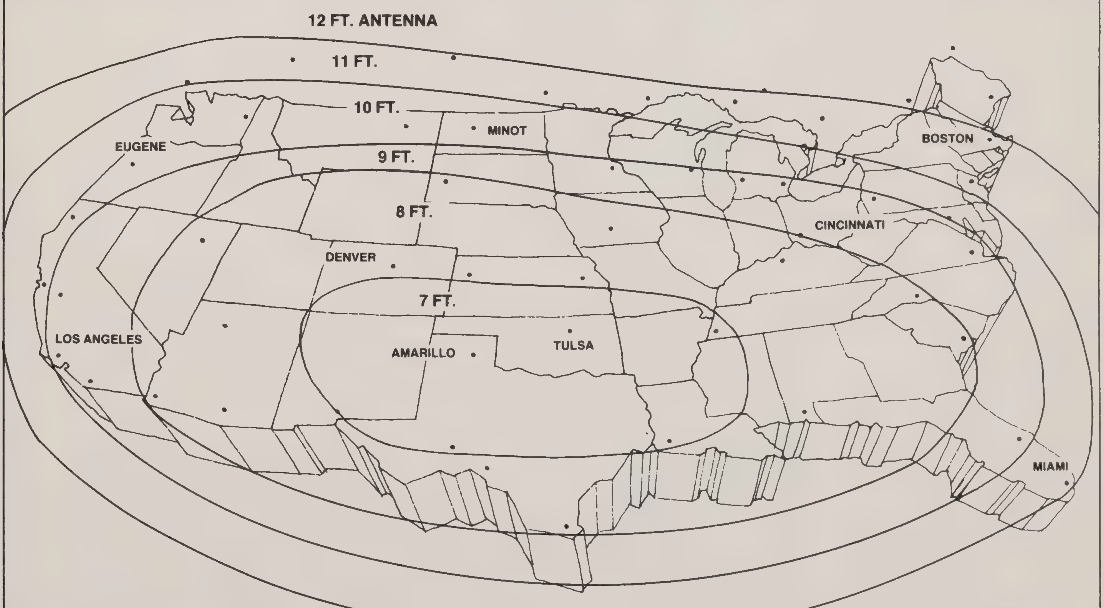
In this fashion, we can construct the following table to show how these antenna size contours relate to dBw of EIRP:

Antenna Size on Maps	EIRP in dBw
5.0	40.12
6.0	38.39
6.5	37.72
7.0	36.92
7.5	36.25
8.0	35.66
9.0	34.50
10.0	33.48
11.0	32.51
12.0	31.64

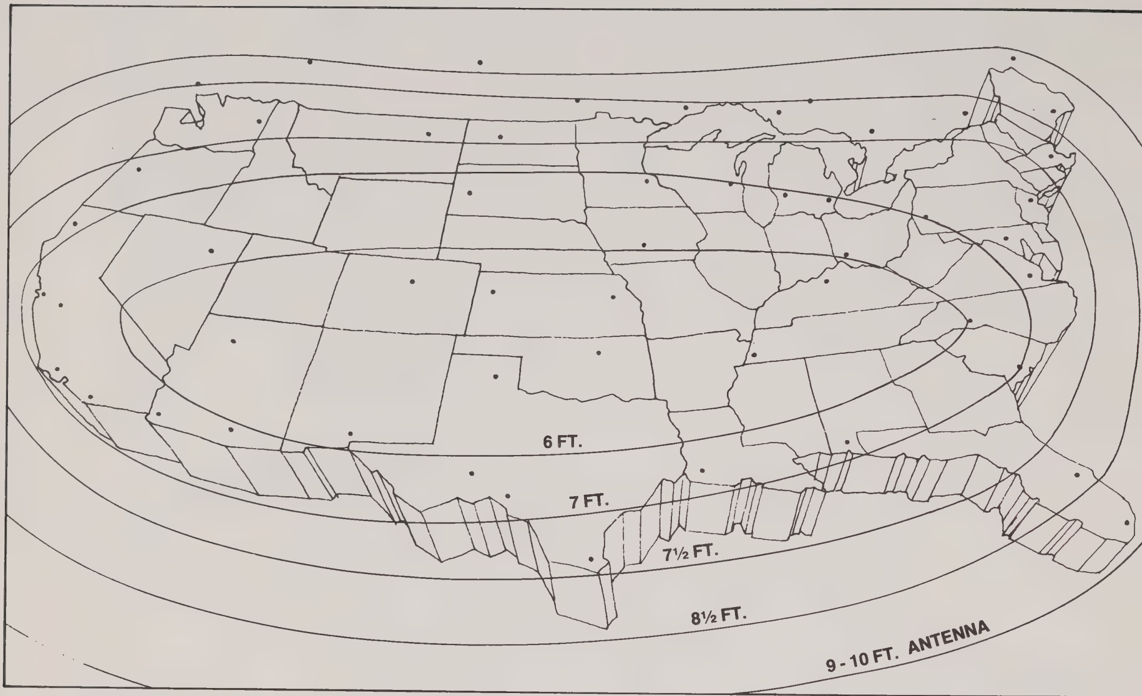
What if we want to use an LNA with a different noise temperature. What size antenna do these maps tell us to use? The link equations again come to the rescue. Assuming that we still want to obtain a C/N of 10.0 dB, well above threshold of most receivers, the G/T must be kept constant. It would be necessary to choose the new antenna/LNA combination having the same G/T as the old. Remember that the system noise temperature depends upon the antenna diameter as well as the LNA noise temperature.



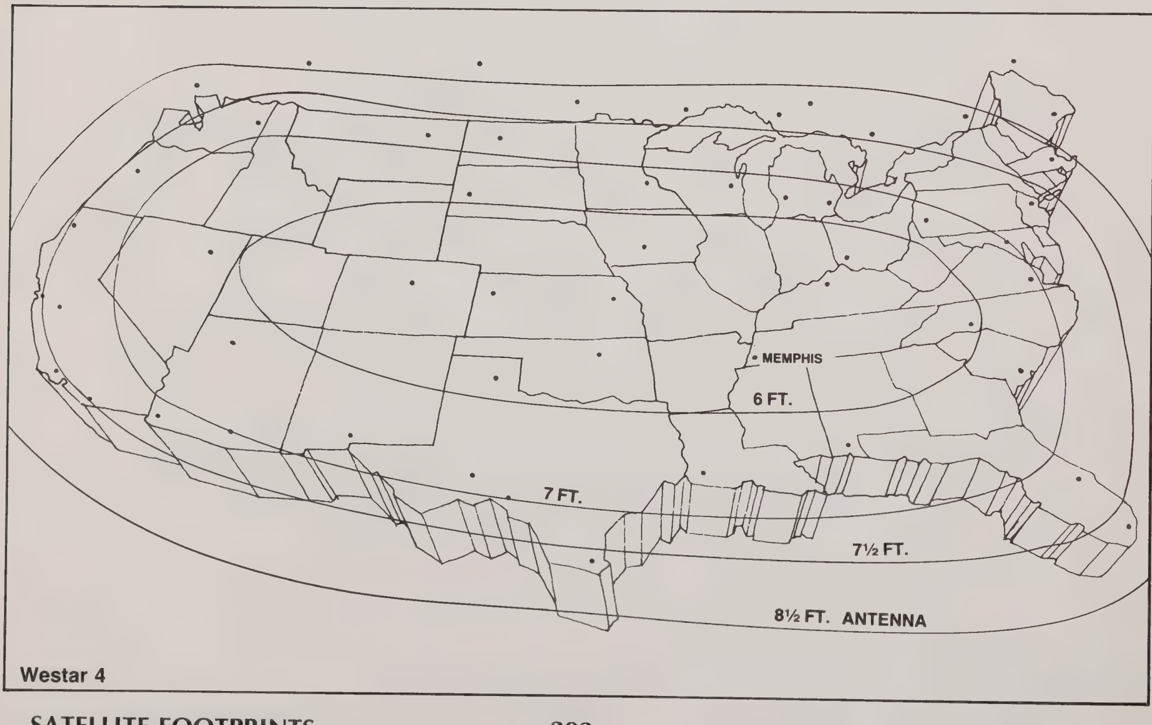
Satcom F4 "Footprint"
High Power



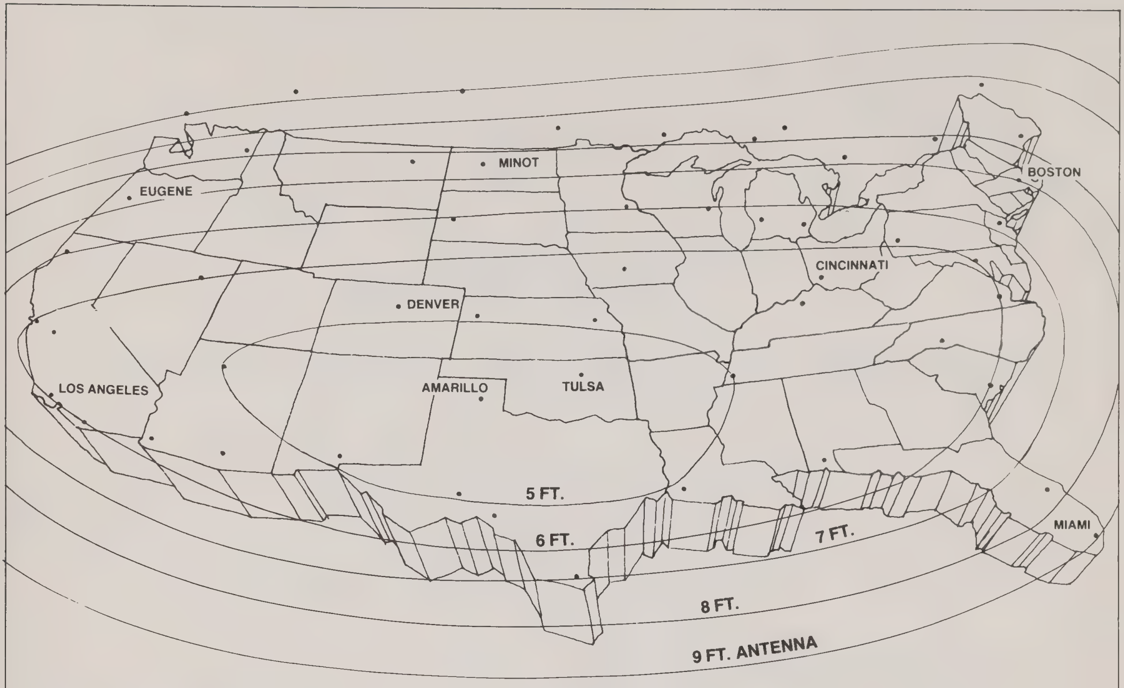
Satcom F4 "Footprint"
Low Power



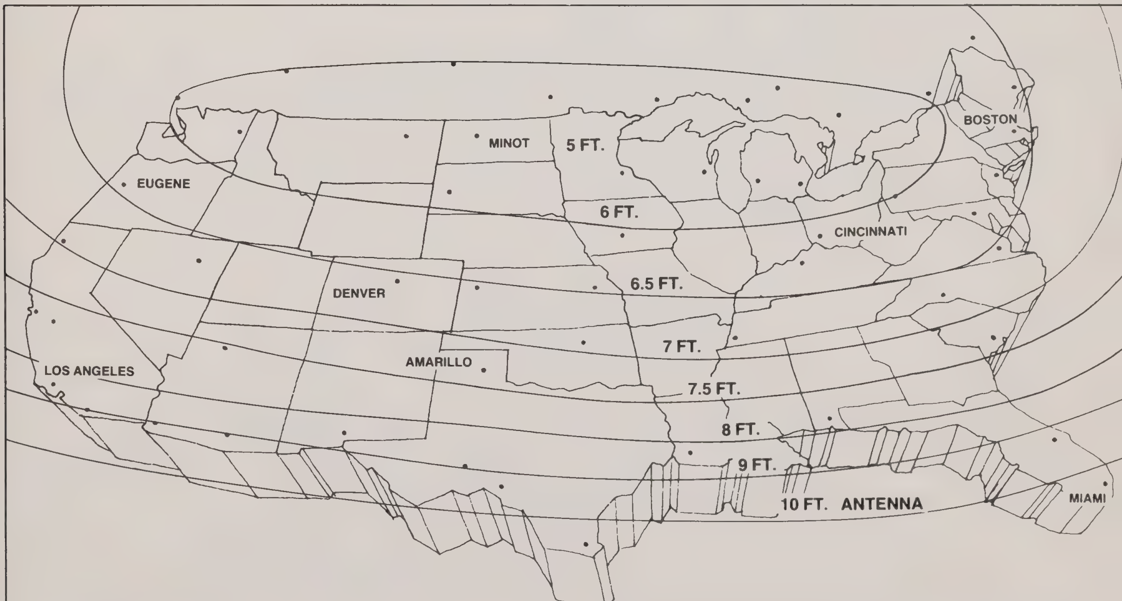
Westar 5



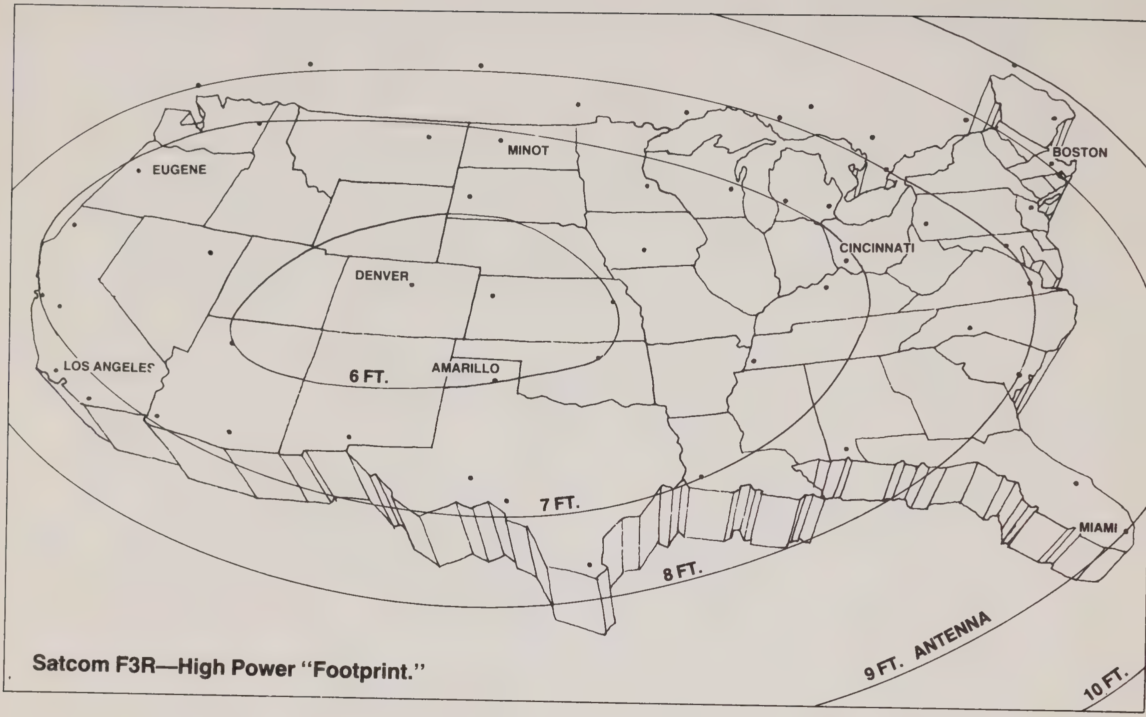
Westar 4



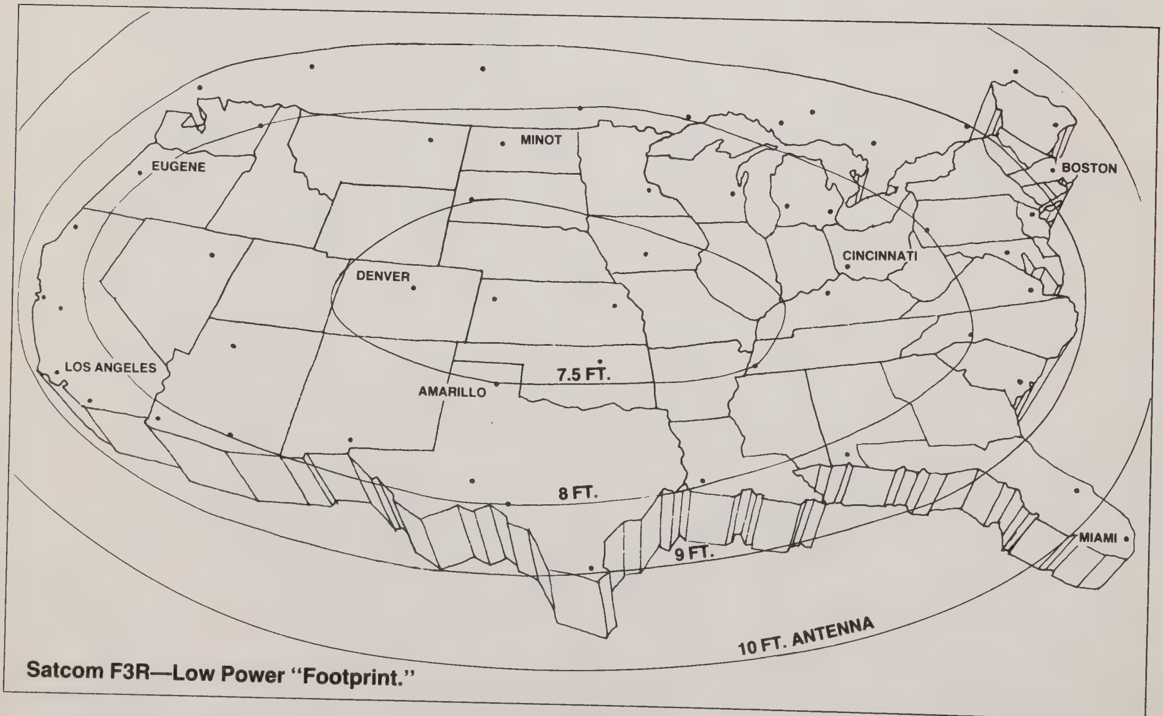
Galaxy 1 "Footprint."



Anki D "Footprint"



Satcom F3R—High Power "Footprint."



Satcom F3R—Low Power "Footprint."

APPENDIX C
SATELLITE TV EQUATIONS

The performance of a satellite TV system can be theoretically calculated by using some general equations. Some of these are presented below.

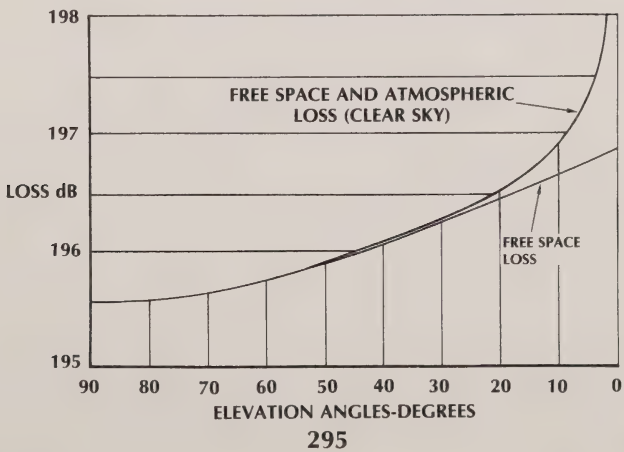
Link Equations

The link equations are used to calculate the signal to noise power reaching the input of a video receiver, the C/N. The link equations are:

$$C/N = \text{EIRP} - \text{Path Loss} + G/T - 10 \log B + 228.6$$

EIRP is the effective isotropic radiated power directed by a downlink antenna to a location below. It is expressed in dBw, decibels relative to one watt.

Path loss measures how much signal is lost on the journey from the communication satellite to the receiving antenna. Losses are mainly due to the "spreading out" of the signal on its long journey but atmospheric absorption also has some effect. Figure C-1 shows how path loss varies with elevation angle. Of course, there will be small variations between rainy or overcast days and clear days. These effects will be very small for C-band transmissions and much larger for Ku-band broadcasts.



G/T, antenna gain to system noise temperature, is the figure of merit of an antenna/feed/LNA system. It was discussed in detail in Chapter II. Remember that the system noise temperature depends upon both the antenna and LNA noise temperatures. (Components further downstream towards the receiver also contribute small amounts of noise.). G/T is given by:

$$G - 10 \log T$$

The second of last term in the link equations above adjusts for the system bandwidth and the final is a constant, called Boltzman's constant.

Antenna Gain

Antenna gain relative to an "isotropic" antenna, one that radiates equally in all directions, is given by:

$$G = E\,(3.14\ D/W)^2$$

E is the antenna efficiency, D is the diameter and W is the wavelength of the microwaves. For example, a 10 foot antenna (120 inch diameter) with a 55% efficiency operating in the C-band, where the wavelength is approximately 2.9 inches, has a gain of:

$$G = 0.55 \times (3.14 \times 120/2.9)^2$$
$$= 9285$$

Expressed in decibels this gain or signal concentration of a factor of 9285 relative to an isotropic antenna is given by:

$$G = 10 \log 9285$$
$$= 39.68 \text{ dBi}$$

Beamwidth

An approximate but very useful formula for 3 dB antenna beamwidth is:

$$\text{Beamwidth} = 70\ W/D$$

where W is the wavelength of the microwave radiation and D is antenna diameter. For example, a 10 foot antenna has a 3 dB beamwidth given by:

$$\text{Beamwidth} = 70 \times 2.9/120$$
$$= 1.69 \text{ degrees}$$

Similarly, a 5 foot antenna would have a calculated beamwidth given by:

$$\text{Beamwidth} = 70 \times 2.9/60$$
$$= 3.38 \text{ degrees}$$

Noise Temperature and Figure

The noise any system generates is proportional to its ambient temperature and the bandwidth of the signal it processes. The larger either of these two quantities, the greater the contributed noise.

$$\text{Noise} = kTB$$

where k is Boltzman's constant, T is the ambient temperature and B is the system bandwidth.

A quantity called noise factor is defined by the ratio of the noise at the output on an electronic component to the noise at its input. In a perfect device whose electronic circuits added no extra noise to a signal, the noise factor would be one.

$$\begin{aligned}\text{Noise Factor} &= \frac{(\text{Ideal Noise} + \text{Internal Noise})}{\text{Ideal Noise}}\\ &= (kBT_0 + kBT)/kBT_0\\ &= (T_0 + T)/T_0\\ &= 1 + T/T_0\\ &= 1 + T/290\end{aligned}$$

T is called the equivalent noise temperature. T_0 is usually taken as 290 K, which equals an average room temperature of about 63 °F.

Noise figure is given by:

$$\text{Noise Figure} = 10 \log (\text{Noise Factor})$$

For example, if the noise figure is 1.7 dB. The equivalent noise temperature is given by:

$$1.7 = 10 \log (1 + T/290)$$

turning this equation inside out:

$$\begin{aligned}1 + T/290 &\doteq 10^{1.7}\\ &= 1.48\\ T/290 &= 0.48\\ T &= 139\ \text{K}\end{aligned}$$

Declination Angle

The declination angle for a polar mount can easily be found from the tables and figures in the early chapters. It can also be calculated from this rather complex looking formula:

$$\text{Declination Angle} = \text{Tan}^{-1}\left[\frac{3964 \sin L}{22300 + 3964(1 - \cos L)}\right]$$

where L is the site latitude. The two numbers in this equation are the radius of the earth and the distance from the surface of the earth to the arc of satellites. For example, the declination angle at 40 degrees latitude is given by:

$$\begin{aligned}\text{Declination} &= \text{Tan}^{-1}\left[\frac{3964 \sin 40°}{22300 + 3964(1 - \cos 40°)}\right]\\ &= \text{Tan}^{1-}\ 0.11\\ &= 6.26\ \text{degrees}\end{aligned}$$

Voltage Standing Wave Ratio

The voltage standing wave ratio, VSWR, is a measure of the amount of input signal reflected back and lost. A perfect device would have no reflective losses and have a VSWR of 1:1. The following table shows how reflected signal power and transmission losses vary with VSWR:

VSWR	Reflected Signal (%)	Transmission Loss (dB)
1.0:1	0	0
1.1:1	0.2	0.01
1.2:1	0.9	0.03
1.3:1	1.6	0.07
1.5:1	4.0	0.18
2.0:1	11.0	0.50

Antenna Parabolic Geometry

The basic equation for a parabolic reflector is given by:

$$y = x^2/4f$$

where f is the focal distance. Another useful formula gives the focal distance f in terms of the antenna diameter and depth:

$$f = \text{diameter}^2/(16 \times \text{depth})$$

Wind Loading

Winds can have very dramatic effects on antennas and their supporting structures. The following tables, kindly provided by Dick Zlotky, president of Earthbound, Inc., give an indication of what types of forces can be expected.

Table C-1 lists the maximum forces on antennas having f/Ds of 3.75 and a look angles of 30 degrees. Smaller f/D or look angles will result in increased forces. Note that the maximum force occurs when the wind is "spooned" through the curvature of the dish with a minimum of turbulence. This occurs when the wind approaches tangentially to the rim of the antenna.

Table C-2 lists the maximum torsion or twisting loads which occur when the wind approaches the antenna from the rear at an angle of approximately 120 degrees from the its main axis.

Table C-3 lists the maximum height allowed above ground level to the center of a dish for a free-standing schedule 40 pipe without intermediate supports. Above this height winds in excess of 100 MPH could bend and possibly break the pipe.

TABLE C-1. SOLID ANTENNA CALCULATED MAXIMUM WIND LOAD

	Wind Velocity (MPH)						
Dish Diameter (feet)	40	50	60	70	80	90	100
4	80	125	180	245	321	406	501
6	180	282	405	552	721	913	1127
8	320	501	721	982	1282	1622	2003
10	500	783	1127	1534	2003	2535	3130
12	721	1127	1623	2209	2885	3651	4507

TABLE C-2. SOLID ANTENNA MAXIMUM TORSION LOADS

	Wind Velocity (MPH)						
Dish Diameter (feet)	40	50	60	70	80	90	100
4	77	120	173	235	307	389	480
6	173	270	389	529	691	875	1080
8	307	480	691	941	1229	1555	1920
10	480	750	1080	1470	1920	2430	3000
12	691	1080	1555	2117	2765	3499	4320

TABLE C-3. MAXIMUM PIPE LENGHT IN 100 MPH WINDS

	Pipe Outer Diameter (inches)					
Dish Diameter (feet)	2.5	3.0	3.5	4.0	5.0	6.0
4	146	237				
5	93	151	205			
6	65	105	143	189		
7	47	77	105	139	234	
8	36	59	81	106	180	276
9		47	63	84	142	218
10			51	68	115	177
11				56	95	146
12					80	123

APPENDIX D BASIC SATELLITE FINDING PROGRAM

This program can be used to find the azimuth and elevation angles to any satellite within view of the Americas. Launching of any new satellites or changes in position of orbiting ones can be easily incorporated. (Provided Courtesy of Echosphere Corporation).

```
                                 SATELLITES' COORDINATES LISTING

For denver colorado..............at longitude 105 ,latitude 39

antenna declination is 6.15 degrees

ALIGNMENT POINT    105 deg west      azimuth: 180      elevation: 44.84   range:  24282.72 m.

INTELSAT IVA-F6    181 deg west      azimuth: 261.08   elevation: 2.14    range:  25969.35 m.
SATCOM V           143 deg west      azimuth: 231.14   elevation: 30.25   range:  24765.95 m.
SATCOM IR          139 deg west      azimuth: 226.98   elevation: 32.8    range:  24673.16 m.
GALAXY I           135 deg west      azimuth: 222.53   elevation: 35.2    range:  24589.22 m.
SATCOM IIIR        131 deg west      azimuth: 217.77   elevation: 37.4    range:  24514.61 m.
COMSTAR IV         127 deg west      azimuth: 212.7    elevation: 39.38   range:  24449.78 m.
WESTAR V           123 deg west      azimuth: 207.3    elevation: 41.11   range:  24395.14 m.
SPACENET I         120 deg west      azimuth: 203.06   elevation: 42.21   range:  24361.04 m.
ANIK C2            116.5 deg west    azimuth: 197.91   elevation: 43.27   range:  24328.89 m.
ANIK D2            114 deg west      azimuth: 194.12   elevation: 43.87   range:  24311.05 m.
ANIK C3            112.5 deg west    azimuth: 191.81   elevation: 44.16   range:  24302.41 m.
ANIK D1            104 deg west      azimuth: 180      elevation: 44.82   range:  24283.07 m.
WESTAR IV          99 deg west       azimuth: 170.51   elevation: 44.4    range:  24295.33 m.
TELSTAR 31         96 deg west       azimuth: 165.87   elevation: 43.87   range:  24311.05 m.
WESTAR III         91 deg west       azimuth: 158.38   elevation: 42.54   range:  24351.01 m.
COMSTAR III        87 deg west       azimuth: 152.69   elevation: 41.11   range:  24395.14 m.
SATCOM IV          83 deg west       azimuth: 147.29   elevation: 39.38   range:  24449.78 m.
WESTAR II          79 deg west       azimuth: 142.22   elevation: 37.4    range:  24514.61 m.
COMSTAR I&II       76 deg west       azimuth: 138.62   elevation: 35.76   range:  24569.67 m.
GALAX6 II          74 deg west       azimuth: 136.32   elevation: 34.61   range:  24609.35 m.
SATCOM IIR         72 deg west       azimuth: 134.1    elevation: 33.42   range:  24651.33 m.
INTELSAT V-FB      53 deg west       azimuth: 116.18   elevation: 20.43   range:  25151.97 m.
INTELSAT IV-F1     50 deg west       azimuth: 113.78   elevation: 18.2    range:  25245.33 m.
INTELSAT V-F2      34.5 deg west     azimuth: 102.56   elevation: 6.38    range:  25770.8 m.
INTELSAT IVA-F1    31 deg west       azimuth: 100.22   elevation: 3.68    range:  25896.67 m.
INTELSAT V-F4      27.5 deg west     azimuth: 97.94    elevation: .98     range:  26024.14 m.
```

```
*
for initial adjustment of true polar mount dishes
10 REM ***DISH AIMER *** ---IBM PC VERSION****
20 REM ***GREG JONSEN ***
30 REM ***THE WORLD OF ECHOSPHERE'S****
50 GOSUB 55000:REM INITIALIZATION
55 GOTO 40000:REM MAIN PROGRAM
57 REM DATA ************************************************
60 DATA ALIGNMENT POINT, 180
70 DATA INTELSAT IVA-F3, 186
72 DATA INTELSAT IVA-F6, 181
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75 DATA SATCOM V, 143, SATCOM IR, 139, GALAXY I, 135
80 DATA SATCOM IIIR, 131, COMSTAR IV, 127
85 DATA WESTAR V, 123, SPACENET I, 120
87 DATA ANIK C2, 116.5, ANIK D2, 114, ANIK C3, 112.5
90 DATA ANIK D1, 104, WESTAR IV, 99
100 DATA TELSTAR 31, 96, WESTAR III, 91, COMSTAR III, 87
110 DATA SATCOM IV, 83, WESTAR II, 79
115 DATA COMSTAR I&II, 76, GALAX6 II, 74, SATCOM IIR, 72
120 DATA INTELSAT V-FB, 53, INTELSAT IV-F1, 50, INTELSAT V-F2, 34.5
130 DATA INTELSAT IVA-F1, 31, INTELSAT V-F4, 27.5, INTELSAT V-F3, 24.5
140 DATA INTELSAT IVA-F4, 21.5, INTELSAT V-F6, 18.5
150 DATA GORIZONT 7, 14, TELECOM II, 8, INTELSAT IVA-F2, 4, INTELSAT IV-FB, 1
155 DATA ECS-2, 350, ECS-1, 347
160 DATA GORIZONT 1, 307, INTELSAT V-F1, 303
165 DATA INTELSAT V-F5, 300, INTELSAT V-F7, 297
167 DATA PALAPA A2, 283, PALAPA A1, 279, RADUGA, 274
199 GOTO 5000
200 INTELSAT IVA-F36, 186
210 INTELSAT IVA-F3, 181
220 DATA SATCOM V, 143
230 DATA SATCOM IR, 139
240 DATA GALAXY I, 135
250 SATCOM IIIR, 131
260 DATA COMSTAR IV, 127
270 DATA WESTAR V, 123
280 DATA ANIK C2, 116.5
290 DATA ANIK D2, 114
300 DATA ANIK D2, 114
310 DATA ANIK C3, 112.5
320 DATA ANIK D1, 104
330 DATA WESTAR IV, 99
5000 REM COMPUTE AND PRINT ****************************************
5005 T1=18: T2=40: T3=60: T4=80
5010 CLS
5030 PRINT TAB(T2)"SATELLITES' COORDINATES LISTING"
5040 PRINT "For ";NM$;"..........";
5050 PRINT"at latitude "AD", longitude "HD
5060 PRINT TAB(16)"*"
5061 IF DV=1 THEN 5070
5062 LPRINT TAB(T2)"SATELLITES' COORDINATES LISTING"
5063 LPRINT: LPRINT "For ";NM$;"..............";
5064 LPRINT"at longitude"HD",latitude"AD
5070 LN=8
5075 REM beginning of i loop ************************
5080 FOR I=1 TO 44
5090      READ SN$, SL
5100      IF I=1 THEN SL=HD
5110      SATLONG=FN RAD(SL):ANTLONG=FN RAD(HD):ANTLAT=FN RAD(AD)
5120      DIFLONG=ANTLONG-SATLONG
5125      IF ANTLAT=0 AND DIFLONG=0 THEN D=0:GOTO 5131
5130      D=FN ACSN(COS(ANTLAT)*COS(DIFLONG))
5131      XX=TAN(D):IF XX=0 THEN XX=1
5135      X=-TAN(ANTLAT)/XX
5136      IF X<-.999 OR X=>.999 THEN C=FN RAD(180):GOTO 5150
5140      C=FN ACSN(X)
5150      IF DIFLONG<0 THEN C=2*PI-C
5160      CD=FN DEG(C)
5163      IF AD<0 AND CD=180 THEN CD=360
5165      XX=SQR(1-COS(D)*COS(D)):IF XX=0 THEN XX=1
5170      X=(COS(D)-(1/K))/XX
```

```
5180      EL=ATN(X)
5190      Y=FN DEG(EL)
5200      IF Y<0 THEN GOTO 5310
5210      RG=RS*SQR(1-(.295*COS(1)*COS(ANTLONG-SATLONG)))
5212      SL=INT(SL*100)/100
5213 IF I<>1 THEN 5221
5214 DC=90-(Y+ABS(AD)):DC=INT(DC*100)/100
5215 PRINT:PRINT"antenna declination is"DC"degrees"
5216 PRINT:IF DV=1 THEN 5222
5217 LPRINT:LPRINT"antenna declination is"DC"degrees":LPRINT
5220 SL=INT(SL*100)/100
5221 IF DV=2 THEN 5230
5222 IF LN<95 THEN GOTO 5230
5224 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:LN=0
5230 PRINT SN$; TAB(T1-1);SL"deg west";
5231 IF DV=1 THEN 5240
5232 LPRINT SN$;TAB(T1);SL"deg west";
5240 CD=INT(CD*100)/100
5243 IF SL>270 AND HD<180 THEN CD=360-CD
5245 IF HD>270 AND SL<180 THEN CD=360-CD
5246 IF AD<0 AND CD=180 THEN CD=360
5250 PRINT TAB(T2-8)"az:"CD;
5251 IF DV=1 THEN 5260
5252 LPRINT TAB(T2)"azimuth:"CD;
5260 Y=INT(Y*100)/100
5270 PRINT TAB(T3-13)"el:";Y;
5273 IF DV=1 THEN 5280
5276 LPRINT TAB(T3)"elevation:";Y;
5280 RG=INT(RG*100)/100
5290 PRINT TAB(T4-20)"range: "RG"m."
5292 IF I=1 THEN PRINT
5295 IF DV=1 THEN 5310
5296 LPRINT TAB(T4)"range: "RG"m."
5297 IF I=1 THEN LPRINT
5298 GOTO 5310
5302 IF LN<32 THEN GOTO 5310
5304 PRINT:INPUT"return to continue";H9$
5306 LN=0:CLS
5310 NEXT I:REM end of i loop ************************
5320 PRINT:PRINT"*"
5330 PRINT"for initial adjustment of true polar mount dishes>"
5340 IF DV=1 THEN 5990
5350 LPRINT:LPRINT"*"
5360 LPRINT"for initial adjustment of true polar mount dishes
5990 RETURN:REM return from whence it gosubbed **********************
40000 REM main program ********************************************
40010 CLS
40020 PRINT TAB(9); "satellite dish aimer"
40030 PRINT:PRINT:PRINT
40040 INPUT"Enter the name of the city:";NM$
40050 IF LEN(NM$)=0 THEN GOTO 50
40060 LOCATE 7,1,1
40070 INPUT"enter antenna latitude:";H9$
40072 IF LEN(H9$)=0 THEN GOTO 50
40074 AD=VAL(H9$)
40080 IF AD<-180 THEN GOTO 40060
40082 IF AD>180 THEN GOTO 40060
40090 LOCATE 9,1,1
40100 INPUT"enter antenna longitude:";H9$
40110 IF LEN(H9$)=0 THEN GOTO 40090
```

```
40120 HD=VAL(H9$)
40130 IF HD<0 THEN HD=360+HD
40140 LOCATE 11,1
40150 INPUT"1=screen, 2=printer:";DV
40155 IF DV=0 THEN GOTO 40090
40160 IF DV<1 OR DV>2 THEN GOTO 40140
40180 GOSUB 5000:REM goto 'compute and print ************************
40190 END:REM T H E   E N D   O F   T H E   P R O G R A M ***********
55000 REM initialization *******************************************
55010 T1=0
55020 T2=0
55030 X=0
55040 EP=0
55050 DG=0
55060 LK=0
55070 BW=0
55080 TH=0
55090 TB=0
55100 NP=0
55110 NG=0
55120 AS=0
55130 EF=0
55140 FQ=0
55150 DI=0
55160 P=0
55170 DG=0
55180 LK=0
55190 BW=0
55200 TH=0
55210 TB=0
55220 NP=0
55230 NG=0
55240 AS=0
55250 EF=0
55260 FQ=0
55270 DI=0
55280 CH=0
55300 K=6.61
55310 PI=3.1415927#
55320 RS=26485
55330 AD=0:REM ....ANTENNA LATITUDE IN DEGREES
55340 HD=0:REM ....ANTENNA LONGITUDE IN DEGREES
55350 SL=0:REM ....SATELLITE LONGITUDE IN DEGREES
55360 SATLONG=0:REM .......SATELLITE LONGITUDE IN RADIANS
55370 ANTLONG=0:REM .......ANTENNA LONGITUDE IN RADIANS
55380 ANTLAT=0:REM .......ANTENNA LATITUDE IN RADIANS
55390 DIFLONG=0:REM .........THE DIFFERENCE BETWEEN ANT.
      LONG AND SAT LONG IN RADIANS
55400 D=0
55410 C=0
55420 CD=0
55430 EL=0
55440 RG=0
55450 I=0
55460 LN=0
55470 H9$=""
55480 NM$=""
55490 SN$=""
55500 DEF FN RAD(X)=X*PI/180
55510 DEF FN DEG(X)=X*180/PI
55520 DEF FN ACSN(X)=(-1)*ATN(X/SQR(-X*X+1))+PI/2
55530 WIDTH "lpt1:",132
55600 RETURN
```

APPENDIX E
GLOSSARY OF TERMS

Alignment
The process of fine tuning a dish or an electronic circuit to maximize its sensitivity and signal receiving capability.

Amplifier
A device used to increase the power of a signal.

Antenna
A device that collects and focuses electromagnetic energy. This process results in an energy gain, which is proportional to surface area for a microwave dish.

Aperture
The area of a parabolic antenna.

Attenuator
A passive device which reduces the power of a signal.

Audio Subcarrier
The carrier wave that transmits audio information between 5 and 8.5 MHz on a satellite broadcast.

Automatic Frequency Control (AFC)
A circuit that locks onto a chosen frequency and will not drift away from that frequency.

Automatic Gain Control (AGC)
A circuit that locks the gain onto a fixed value and thus compensates for varying input signal levels keeping the output constant.

Azimuth-Elevation (Az-El) Mount
An antenna mount which tracks satellites by moving in two directions: the azimuth in the horizontal plane; and elevation up from the horizon.

Azimuth
Degrees of rotation clockwise from true north.

Bandpass Filter
A circuit or device that allows only a specified range of frequencies to pass through a circuit.

Bandwidth
The frequency range allowed to pass through any circuit.

Baseband
The pure audio and video signal without a carrier wave. Satellite signals have audio baseband information from near zero frequency to 3400 Hertz. Video baseband is from zero to 4.2 MHz.

Beamwidth
A measure used to describe the width of vision of an antenna. It is measured between the 3 dB half power points in angles.

Block Downconversion
The process of lowering the entire satellite band of frequencies in one step to some intermediate range to be processed inside the video reciever. Multiple receivers can indepently select channels by processing this block of signals.

BNC Connector
A weatherproof twist lock coax connector used on some brands of satellite receivers and standard on commercial video equipment.

Boresight
That direction along the axis of either a transmitting or a receiving antenna.

Buttonhook Feed
A rod shaped like a question mark supporting the feedhorn and LNA. In commercial dishes a buttonhook feed often is a hollow waveguide that directs signals from the feedhorn to an LNA behind the dish.

CATV
An abbreviation for Community Antenna Television used to describe cable TV.

C-Band
The 3.7 to 4.2 GHz band of frequencies at which some broadcast satellites operate.

Carrier
A single frequency radio signal that is modulated to carry information.

Carrier-to-Noise Ratio (C/N)
The ratio of the received carrier power to the noise power in a given bandwidth. The C/N is an indicator of how well an earth station will perform in a particular location and is calculated from satellite power levels, antenna gain and the combined antenna and LNA noise temperature.

Carrier-to-Noise Ratio (G/kT)
The C/N expressed in decibels per Hertz of signal bandwidth.

Cassegrain Feed System
An antenna feed design that includes a primary reflector, the dish, and a secondary reflector which redirects microwaves via a waveguide to an LNA.

Channel
A segment of bandwidth used for one communications link.

Circular Polarization
Electromagnetic waves whose electric field uniformly rotates along the signal path. Broadcasts used by Intelsat and other international satellites use circular not horizontally or vertically polarized waves.

Clark Belt
The circular orbital belt at 22,247 miles above the equator, named after the writer Arthur C. Clarke, in which satellites travel at the same speed as the earth's rotation. Also called the geosynchronous or geostationary orbit.

Coaxial Cable
A cable for transmitting high frequency electrical signals with low loss. It is componsed of an internal conducting wire surrounded by a insulating dielectric which is covered by a metal shield.

Cross Polarization
Term to describe signals of the opposite polarization than the one being transmitted. Cross-polarization discrimination refers to the ability of a feed to detect one polarity and reject the opposite polarity signals.

Decibel (dB)
A term that expresses the ratio of power levels used to indicate gains or losses of signals. Decibels relative to one watt or milliwatt are abbreviated as dBw and dBm, respectively.

Direct Broadcast Satellite (DBS)
A term commonly used to describe satellite broadcasts directly to homes using the Ku-band, 12 to 14 GHz.

DC Power Block
A device which stops the flow of DC power but permits passage of higher frequency signals.

Declination Offset Angle
The adjustment angle of a polar mount between the polar axis and the plane of a satellite antenna used to aim at the geosynchronous arc.

Demodulator
A device which extracts the signal from the transmitted carrier wave.

Detent Tuning
Tuning onto a satellite channel by selecting a preset resistance.

Digital
Describes a system or device in which information is transferred by electrical "on-off," "high-low," or "1/0" pulses instead of continuously varying signals as in an analog message.

Dish
Jargon for a parabolic microwave antenna.

Dish Illumination
Describes how a feedhorn "sees" the surface of a dish as well as the surrounding terrain.

Downconverter
The circuit associated with a satellite receiver that lowers the high frequency signal to a lower, intermediate range. There are three distinct types of downconversion: single downconversion; dual downconversion; and block downconversion.

Downlink Antenna
The antenna on-board a satellite which relays signals back to earth.

Dual Feedhorn
A feedhorn which can simultaneously receive both horizontally and vertically polarized signals.

Earth Station
A complete satellite receiving or transmitting station including the antenna, electronics and all associated equipment necessary to receive or transmit satellite signals.

Effective Isotropic Radiated Power (EIRP)
A measure of the signal strength that a satellite transmits towards the earth below. The EIRP is highest at the center of the beam and decreases away from this boresight.

Elevation Angle
The vertical angle measured from the horizon up to a targeted satellite.

FCC
The Federal Communications Commission, the regulatory board which sets standards for communications within the United States.

f/D Ratio
The ratio of an antenna's focal length to diameter. It describes the "depth" of a dish.

Feedhorn
A device that collects microwave signals reflected from the surface of an antenna. It is mounted at the focus in all prime focus parabolic antennas.

Focal Length
The distance from the reflective surface of a parabola to the point at which incoming satellite signals are focused, the focal point.

Footprint
The geographic area towards which a satellite downlink antenna directs its signal. The measure of strength of this footprint is the EIRP.

Frequency
The number of vibrations per second of an electromagnetic signal expressed in cycles per second or Hertz.

Gain
The amount of amplification of output to input power often expressed as a multiplication factor or in decibels.

Gain-to-Noise Temperature Ratio (G/T)
The figure of merit of an antenna and LNA. The higher the G/T the better the reception capabilities of an earth station.

Geostationary Orbit
See Clarke Belt.

GigaHertz (GHz)
Billions of cycles per second.

Global Beam
A footprint pattern used by communication satellites targeting nearly 40% of the earth's surface below. Many Intelsat satellites use global beams.

Ground Noise
Unwanted microwave signals generated from the warm ground and detected by a dish.

Hardline
A low-loss coaxial cable that has a continuous hard metal shield instead of a conductive braid around the outer perimeter.

Heliax
A thick low-loss cable used at high frequencies also known as hardline.

Inclinometer
An instrument used to measure the angle of elevation to a satellite from the surface or the earth.

Intermediate Frequency (IF)
A middle range frequency generated after downconversion in a satellite receiver.

INTELSAT
The International Telecommunication Satellite Consortium, a body of 154 countries working towards a common goal of improved worldwide satellite communications.

Isolator
A device that allows signals to pass unobstructed in one direction but which attenuates their strength in the reverse direction.

Kelvin Degrees (K)
The temperature above absolute zero, the temperature at which all molecular motion stops, graduated in units the same size as degrees Celcius (°C). Absolute zero equals -273 °C or -459 °F.

Ku-Band
The microwave frequency band between 11.7 and 12.2 GHz.

Latitude
The measurement of a position on the surface of the earth north or south of the equator measured in degrees of angle.

Line Amplifier
An amplifier in a transmission line that boosts the strength of a signal.

Local Oscillator
A device used to supply a stable single frequency to an upconverter of a downconverter. The local oscillator signal is mixed with the carrier wave to change its frequency.

Longitude
The distance east or west of the prime meridian measured in degrees.

Low Noise Amplifier (LNA)
A device that receives and amplifies the weak satellite signal reflected by an antenna via a feedhorn. LNAs have noise temperature rated in degrees Kelvin.

Low Noise Block Downconverter (LNB)
An LNA which also downconverts the whole 500 MHz satellite bandwidth at once to an intermediate frequency range.

Low Noise Converter (LNC)
An LNA and a conventional downconverter housed in one weatherproof box.

Magnetic Variation
The difference between true north and the north indication of a compass.

Master Antenna TV (MATV)
Broadcast receiving stations that use a high-quality UHF and/or VHF antennas centrally located and that relay this TV to a local apartment/condo or group-housing complex.

MegaHertz (MHz)
Millions of cycles per second.

Microwave
The frequency range from approximately 500 MHz to 30 GHz.

Modulation
A process in which a message is added to a carrier wave. This can be done by frequency or amplitude variation, known as AM or FM, respectively.

Mount
The structure that supports an earth station antenna. Polar and az-el mounts are the most common variety.

N-Connector
A low-loss coaxial cable connector used a C-band microwave frequencies.

NTSC
The National Television Standards Committee which sets standards for North American TV broadcasts.

Noise
An unwanted signal which interferes with reception of the desired information. Noise is often expressed in degrees Kelvin or in decibels.

Noise Figure
The ratio of the actual noise power generated at the input of an amplifier to that which would be generated in an ideal resistor. The lower the noise figure, the better the device.

Noise Temperature
A measure of the amount of thermal noise present in a system or a device. The lower the noise temperature, the better the device.

Offset Feed
A feed which is offset from the center of a reflector. This configuration does not block the antenna aperature.

PAL
Phase Alternate Line. A European color TV format different from the American NTSC.

Pad
A concrete base upon which a supporting pole and dish can be mounted.

Parabola
The geometric shape that has the property of reflecting all signals parallel to its axis to one point, the focal point.

Polar Mount
An antenna mount that permits all satellites in the geosynchronous arc to be scanned with movement of only one axis.

Polarization
A characteristic of the electromagnetic wave. Four senses of polarization are used in satellite transmissions: horizontal; vertical; right-hand circular; and left-hand circular.

Prime Focus Antenna
A parabolic dish having the feed/LNA assembly at the focal point in front of the antenna.

Radio Frequency
The approximately 10 KHz to 100 GHz electromagnetic band of frequencies used for man-made communication.

Satellite Receiver
The in-doors electronic component of an earth station which downconverts, processes and prepares satellite signals for viewing or listening.

Scrambling
A method of altering a signal indentity to prevent its unauthorized reception by persons not having decoders.

Side Lobe
A construct used to describe an antenna's ability to detect off-axis signals. The larger the side lobes, the more noise and interference a dish can detect.

Single Channel Per Carrier (SCPC)
A satellite transmission system that employs a separate carrier for each channel. As opposed to frequency division mulitplexing that combines many channels on a single carrier.

Signal-to-Noise Ratio (S/N)
The ratio of signal power to noise power in a specified bandwidth, usually expressed in decibels.

Sparklies
Small black and/or white blips or dots in a television picture indicating an insufficient signal-to-noise ratio.

Spherical Antenna
An antenna system using a section of a spherical reflector to focus one or more satellite signals to one or a series of focal areas.

Splitter
A device that takes a signal and splits it into two or more identical but lower power signals.

Thermal Noise
Random, underired electrical signals caused by molecular motion known, more familiarly, as noise.

Threshold
A minimal signal to noise input required to allow a video receiver to deliver an acceptable picture.

Transponder
A microwave repeater, receiver and transmitter, in a satellite used to amplify and change frequency of an uplinked communication channel.

Trap
An electronic device that attenuates a selected band of frequencies in a signal.

Upconverter
A device that increases the frequency of a transmitted signal.

Uplink
The earth station electronics and antenna which transmits information to a communication satellite.

Voltage Tuned Oscillator (VTO)
An electronic circuit used in a satellite receiver that generates a frequency used in selecting channels.

Video Monitor
A television that accepts unmodulated baseband signals to reproduce a broadcast.

APPENDIX F REFERENCE MATERIALS

Satellite TV Guides

Channel Guide
300 East Hampden, Suite 340
Englewood, CO 80110
(303) 654-3006

On Sat
P.O. Box 2384
Shelby, NC 28151
(800) 438-2020

Orbit
P.O. Box 1700
Hailey, ID 83333
(800) 792-5541

Satellite Dish Magazine
P.O Box 8
Memphis, TN 38101
(901) 521-1580

Satellite TV Weekly
P.O. Box 308
928 Main Street
Fortuna, CA 95540
(800) 556-8787

Satellite TV Guide
P.O. Box 8266
Edmonton, Alberta T6H 4P1
Canada
(403) 425-1169

Trade Publications

Coops Satellite Digest
P.O. Box 100858
Ft. Lauderdale, FL 33310
(305) 771-0505

Private Cable
Weisner Publishing Company
5594 S. Prince Street
Littleton, CO 80120
(303) 798-1274

Satellite Communications
Cardiff Publishing
6430 S. Yosemite Street
Englewood, CO 80111
(303) 694-1522

Satellite Business
Steve Tolin Enterprises
P.O. Box 2772
Palm Springs, CA 92263
(619)323-2000

Satellite Dealer
CommTek, Inc.
P.O. Box 1048
Hailey, ID 83333
(208) 788-4936

Satellite Retailer
P.O. Box 2384
Shelby NC 28151
(704) 482-9673

Satellite TV Opportunities
1717 East University Avenue
Oxford, MS 38655
(601) 236-5510

STV
501 N. Washington Street
Shelby, NC 28150
(704) 482-9673

TVRO Technology
Weisner Publications
5951 South Middlefield Road
Littleton, CO 80123
(303) 798-1274

Reference Books

(Order Form on Next Page)

ASTI - The Avoidance/Suppression Approach to Eliminating Tererstrial Interference at TVRO Earth Stations

by Glyn Bostick, John Fannetti and William Johnson

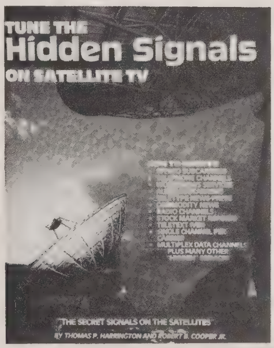
Hidden Signals on Satellite TV
by Thomas P. Harrington and Bob Cooper, Jr.

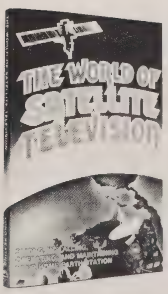
Satellites Today - The Complete Guide to Satellite Television
by Frank Baylin

Satellite Almanac
by CommTek Publishing

TVRO Handbook from Coops Digest

The World of Satellite Television
by Mark Long and Jeffrey Keating





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Book	Number of Copies	Unit Cost	Total Cost
The Home Satellite TV Installation and Troubleshooting Manual		$29.95	
Satellites Today - The Complete Guide to Satellite Television		9.95	
ASTI Manual		59.00	
The Hidden Signals on Satellite TV		14.95	
The World Satellite Almanac		29.95	
The Satellite Television Handbook		19.95	
The World of Satellite Television		9.95	

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Total Cost $________

Name ______________________________

Company ______________________________

Address ______________________________

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Telephone ______________________________

Please send money order or check to:

Baylin/Gale Productions
Suite D
1905 Mariposa Street
Boulder, Colorado 80302
(303) 449-4551

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The Hidden Signals on Satellite TV		14.95	
The World Satellite Almanac		29.95	
The Satellite Television Handbook		19.95	
The World of Satellite Television		9.95	

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The Hidden Signals on Satellite TV		14.95	
The World Satellite Almanac		29.95	
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Everything you need to know to understand, select equipment, install and troubleshoot satellite television systems is here, in this book. The information is presented in a clear, easily readable style, and is designed for anyone havin curiosity about the rapidly growing, very profitable satellite television business. This is a must book for every satellite television dealer and the many thousands who will install their own systems.

"This book . . . puts it all in one place and will make it ...ible to throw out that old collection."
H. Taylor Howard
Director of Research
Chaparral Communications, Inc.

oth sales and
founder of ConSol Networ
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onducts training semina
blished Satellites Tod y - The
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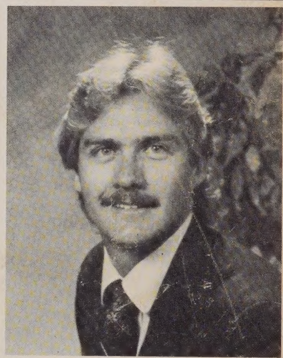

BRENT GALE
President of GeoTrac Corporation

Brent Gale has installed over 1000 satellite television systems throughout the world including one at Arthur C. Clarke's residence in Sri Lanka. He teaches the SPACE dealer certification troubleshooting course and has taught their installation section. Prior to his post as president of GeoTrac, Inc., he was the Senior Technical Advisor for Echosphere Corporation. He has helped shape the industry by providing design help on many receivers, actuators and dishes on the market today. He is one of the principle designers of the GeoTrac antenna and horizon-to-horizon mount.

His eleven years experience in electronics includes 5 years with the Air Force where he worked on electronic digital switching systems and was extensively trained in satellite tracking systems. Prior to that he installed headend equipment and serviced cable television systems for Cable Com General.